**ECE 3512: SignalS – Continuous and Discrete**

# Recitation No. 2: Average Power

The goal of this laboratory is to understand the concept of average power and the generalization of this concept from what you learned in Circuits. We will work with four signals:

(1) 

(2) 

(3) 

(4) The audio signal located here:

<http://www.isip.piconepress.com/courses/temple/ece_3512/recitation/2014_fall/rec_01/rec_01_speech.raw>

For these experiments, we will consider a simple circuit with a voltage source connected across a 2Ω resistor. The tasks to be accomplished in this lab are:

1. For signal no. 1, derive an expression for the power dissipated in the resistor. Start with the concept of instantaneous power and compute its average, as explained in the class handout located at:

<http://www.isip.piconepress.com/courses/temple/ece_3512/exams/2014_fall/quiz_01_v00_solution.docx>

and derive the familiar expression  where A is the amplitude of the sinewave. Based on this can you explain what RMS amplitude is and why the RMS value of a sinewave is 0.707 multiplied by its amplitude? Does RMS apply to signals of all shapes (e.g., signal no. 3)? Explain.

1. For signal no. 1, create a Multisim simulation that computes the average power dissipated in the resistor. Demonstrate that Multisim matches the result computed in task no. 1. Modify your simulation to use signal no. 3 and also compute the average power dissipated in the resistor. Explain why this number is greater or less than the value for signal no. 1. Suppose you connected a capacitor in series with the resistor (so the voltage source is now connected across both components). How would your answer change? Use your Multisim simulation to explore this issue. (Hint: think about the DC value of the triangle wave and the impedance of the capacitor).
2. Use the MATLAB symbolic integration tools to compute the power dissipated in the resistor for signal no. 1. The result for signal no. 1 should match your analytic result and your Multisim simulation.
3. For signal no. 2, use a period of 1.0 secs. Set f1 = 1.0 Hz. Plot the average power dissipated in the resistor for f2 = [0.5 Hz, 2.0 Hz] in steps of 0.01 Hz. Explain/justify your answers. Show that these match what Multisim predicts for several important cases (e.g., frequencies that are not commensurate). Repeat this plot for f1 = 1.33 Hz.
4. For signal no. 3, compute the power dissipated in the resistor using Multisim and MATLAB. Demonstrate that your results match. Can you explain this result? (Hint: Fourier Series.)
5. Compute the power of signal no. 4. Hmmm... we have two problems here: (1) it is a discrete-time signal and (2) it is a time-varying signal. How do we define a period? Yet, we need some concept of power or energy so we don’t blow your ears off when we deliver this signal (like music) to your MP3 player.

Let’s try an approximation. This is an 8 kHz sampled signal, so let’s break the signal into “windows.” Let M denote the frame duration in samples, and N denote the window duration in samples. Start with sample no. M/2. Collect the samples from (M/2-N/2 to M/2+N/2-1) into a vector, and compute: . Increment M: M = iM + M/2 for i = 0, 1, 2, ... and repeat this calculation for each value of i. Iterate over the entire length of the file. Use zero values for any array indices that fall outside of the range of your original vector (we call this zero-stuffing).

Plot the Pavg as a function of i (which is really time since each sample corresponds to a time interval of 1/8000 Hz).

Now, here is the fun part. Plot Pavg as a function of time for the following combinations: M=40, 80, 160, 320; N=80, 160, 320, 640. This will give you 16 plots. Compare these to a plot of the actual signal waveform.

What can you conclude from this analysis? How does this relate to the spectrogram question of Recitation No. 1?

In case you don’t think estimation of the power of a nonstationary signal is important, let me point out several examples where this is critical:

1. How annoying is when you channel surf on cable and each station is delivered with a different loudness, so you are continuously adjusting the volume? (The cable industry is terrible about this.)
2. What if you had to adjust the volume level for every song you listened to on your MP3 player?
3. Why are commercials often played at higher volume levels than the program content?
4. For those music buffs, you might recall the “Volume Wars”: <http://music.tutsplus.com/articles/are-the-volume-wars-killing-music-which-side-are-you-on--audio-8381>. The level at which music is recorded and broadcast is very controversial. Software that deals with this uses the above process as the first step in measuring “loudness.”