Fall 2021 EE 313 Linear Systems and Signals Prof. Evans

**Homework #2 Fourier Series**

Assigned on Sunday, September 5, 2021

Due on Friday, September 10, 2021, by 11:59 pm via Canvas submission

*Late homework is subject to a penalty of two points per minute late*.

***Reading***: McClellan, Schafer and Yoder, *Signal Processing First*, 2003, Ch. 3. [Errata](http://dspfirst.gatech.edu/spfirst/SPFirst-errata.pdf).

Companion Web site with demos and other supplemental information: <http://dspfirst.gatech.edu/>

Web site contains solutions to selected homework problems from *DSP First*.

E-mail address for Mr. Faris Tabbara (TA) is [firas.tabbara@utexas.edu](mailto:firas.tabbara@utexas.edu). Lecture hours and office hours for Mr. Tabbara and Prof. Evans on Zoom (see links on the [Canvas](https://utexas.instructure.com/courses/1311644) calendar) follow:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Time Slot*** | ***Monday*** | ***Tuesday*** | ***Wednesday*** | ***Thursday*** | ***Friday*** |
| **9:30 am** |  |  |  | Evans  (Zoom) |  |
| **10:00 am** |  |  |  | Evans  (Zoom) |  |
| **10:30 am** |  |  |  |  |  |
| **11:00 am** |  | Evans (EER 1.516) |  | Evans (EER 1.516) |  |
| **11:30 am** |  | Evans (EER 1.516) |  | Evans (EER 1.516) |  |
| **12:00 pm** |  | Evans (EER 1.516) |  | Evans (EER 1.516) |  |
| **12:30 pm** |  | Evans  (Zoom) |  |  |  |
| **1:00 pm** |  | Evans (Zoom) |  |  |  |
| **1:30 pm** |  |  |  |  |  |
| **2:00 pm** |  |  |  |  | Evans (Zoom) |
| **2:30 pm** |  |  |  |  | Evans (Zoom) |
| **3:00 pm** |  |  |  |  | Tabbara (Zoom) |
| **3:30 pm** |  |  | Tabbara (Zoom) |  | Tabbara (Zoom) |
| **4:00 pm** |  |  | Tabbara (Zoom) |  | Tabbara (Zoom) |
| **4:30 pm** |  |  | Tabbara (Zoom) |  |  |

As stated on the course descriptor, “Discussion of homework questions is encouraged. Please be sure to submit your own independent homework solution.”

In your solutions, please put all work for problem 1 together, then all work for problem 2 together, etc. Please see the guidelines for writing your solutions on the homework page.

**1. Fourier Synthesis. 25 points.**

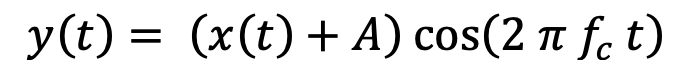
*Signal Processing First*, problem P-3.2, page 65, but use the following spectrum:

Timeline

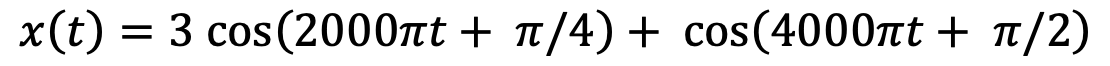
Description automatically generated

**2. Amplitude Modulation. 24 points.**

In AM radio, the transmitted signal (voice or music) is modulated by a sinusoid at the assigned broadcast frequency of the AM station. For example, the Zone Austin Sports Talk in Austin has a carrier frequency *fc* of 1300 kHz. For example, if *x*(*t*) is the voice/music signal, then the transmitted signal would be:



where *A* is a constant. (*A* is introduced to make the AM receiver design easier, in which case *A* must be chosen to be larger than the maximum value of *v*(*t*).) Suppose that the signal that is to be transmitted is



Draw the spectrum for *y*(*t*) assuming a carrier frequency of 1300 kHz with *A* = 2. Hint: Substitute for *x*(*t*) and expand *y*(*t*) into a sum of cosine terms of three different frequencies.

**3. Chirp Signal. 27 points.**

This problem analyzes the chirp signal, which is used in sonar and radar systems, indoor positioning, test and measurement, and 4G cellular communications. The chirp signal is a sinusoid whose principal frequency content increases (or decreases) over time. A chirp signal has the form

*c*(*t*) = cos( *θ*(*t*) ) where *θ*(*t*) = 2  ( *f*0 + ½ *f*step *t* ) *t* = 2  *f*0 *t* +  *f*step *t*2

The principal frequency is *f*0 when *t* = 0 and then changes over time at a rate of *f*step in units of Hz/s. The principal frequency of a sinusoid at a given point in time is called the *instantaneous frequency*, and it is defined as *dθ*(*t*) / *dt* in units of rad/s. Here, *dθ*(*t*) / *dt =* 2  *f*0 + 2  *f*step *t* = 2  (*f*0 + *f*step *t*).

1. Generate a chirp signal that lasts 10s with *f*0 = 20 Hz and *f*step = 420 Hz/s. Use sampling rate *fs*of 44100 Hz. The chirp will sweep through the frequencies of the keys on an 88-key piano:   
   <https://en.wikipedia.org/wiki/Piano_key_frequencies>. Here is Matlab code to help get started:

%%% Generate a chirp signal with frequency increasing

%%% from f0 to (f0 + fstep time) over time seconds

time = 10;

f0 = 20;

fstep = 420;

fs = 44100;

Ts = 1 / fs;

t = 0 : Ts : time;

%%% Add code here to define the chirp signal y = cos( angle(t) )

1. Play the chirp signal as an audio signal. Describe what you hear. The Matlab command is

sound(y, fs);

1. Plot the spectrogram of the chirp signal using the spectrogram function in Matlab and describe the visual representation. Here’s Matlab code to get started:

figure;

spectrogram(y, hamming(256), 128, 256, fs, 'yaxis');

Provide all the Matlab code that you used in solving this problem.

**4. Audio Effects. 24 points.**

Consider the signal *x*(*t*) = cos(2  *f*0 *t*) where *f*0 = 440 Hz which an ‘A’ note on the Western scale.

Write MATLAB code to implement the following audio effects. Play each audio signal over 0 ≤ *t* ≤ 5 and use a sampling rate of 8000 Hz:

1. *y*(*t*) = | *x*(*t*) |
2. *y*(*t*) = *x2*(*t*)
3. *y*(*t*) = *x4*(*t*)
4. *y*(*t*) = cos(*x*(*t*))

For each part, give a mathematical analysis to determine what frequencies are present in *y*(*t*) and play *y*(*t*) as an audio signal and describe what you hear vs. *x*(*t*).

Note that in parts (a), (b) and (c), *y*(*t*) will have a DC value. You can either remove the DC value from *y*(*t*) and play the resulting signal with the sound command, or simply play *y*(*t*) using the soundsc command. To remove the DC (average) value from vector sig in MATLAB, use sig – mean(sig).

Please submit the MATLAB code that you have written.