EE160 - Fall 2023
Homework # 6

San José State University
Due: Thu. 11/2/23 11:59 PM

1. Quadrature modulation

   Download MATLAB Simulink model `QM_coherent_random_2020.slx` from Canvas and run it using your student ID number as seed. The model simulates quadrature modulation of two random message signals based on your student ID number and plots the message signals before quadrature modulation, after quadrature demodulation as well as the modulated signal. In addition, the spectrum of the modulated and demodulated signals are produced.

   Run the model and include all the figures in your solution. Verify that the demodulated signals are practically identical to the message signals

2. A quadrature modulator (QM) transmits message signals $m_I(t) = \text{sinc}(100t)$ and $m_Q(t) = \text{sinc}^2(50t)$. The carrier frequency is 400 Hz.

   (a) Sketch carefully the amplitude spectrum $|U_{\text{QM}}(f)|$ of the modulated signal.

   (b) Use the spectral density $U_{\text{QM}}(f)$ of the QM signal to show that the in-phase message signal $m_I(t)$ can be recovered by first multiplying the modulated signal $u_{\text{QM}}(t)$ by $\cos(800\pi t)$ and then passing the result $z_I(t) = u_{\text{QM}}(t)\cos(800\pi t)$ through a lowpass filter (LPF) of bandwidth 50 Hz.

3. Computer model of a superheterodyne receiver

   Download MATLAB simulink model `AM_superheterodyne_image_2020.slx` from Canvas. The model simulates the image problem of a heterodyne receiver for the commercial AM radio band. The desired RF channel carries a *sinusoidal* message signal and is located at at $f_{\text{RF}} = 560$ kHz. The intermediate frequency (IF) is chosen to be the standard value $f_{\text{IF}} = 455$ kHz.

   Four stations are received including the image channel with a *ramp* message signal located at $f_{\text{IM}} = f_{\text{RF}} + 2\, f_{\text{IM}} = 1470$ kHz. That is, channel 1 (desired): 560 kHz; channel 2: 920 kHz; channel 3: 970 kHz; and channel 4 (image): 1470 kHz.

   Before running the model you need to set the seed variable equal to the last four digits of your student ID. (Example: If the last four digits are 1234, enter `seed = 1234;` in the command window.)

   (a) Run the model. Note that in the model the channel filter is bypassed. Sketch or include the figures of

      i. The spectrum of the received signal

      ii. The demodulated signal

   (b) Double-click on the manual switch to connect the channel filter. Repeat part (a). *Comment on the effects that the filter has on the demodulated signal.*

4. Computer model of an FM system using a phase-locked loop receiver

   Download MATLAB Simulink model `FM_PLL_2021b.slx` from Canvas. The model illustrates waveforms and spectral densities of FM signals with a sinusoidal message signal using a voltage-controlled oscillator (VCO) to modulate and demodulate the signals. The signal generator outputs a sinusoidal signal of frequency $f_m = 15$ Hz (default value). The modulator has a maximum frequency deviation $\Delta f_{\max} = 200$ Hz and carrier frequency $f_c = 1$ kHz. The demodulator uses a PLL with a VCO of maximum frequency deviation 300 Hz and center frequency 1 kHz.

   (a) Run the model, capture or sketch the spectrum, and determine the modulation index β_f for $f_m = 15$ Hz (default).

   (b) Determine the modulating frequency value f_m Hz such that $\beta_f = 2.4$. Modify the value of f_m in the model, run it and capture or sketch the spectrum.

5. Spectrum and bandwidth of a sinusoidal modulated FM signal

   Download script `FMsinusoidal_spectrum_and_pcnt_BW.m` from Canvas. Given the modulation index β_f, the script plots the amplitude spectrum $|U(f)|$ of a sinusoidal FM signal, estimates the bandwidth B_P that contains a given percent of the total power, and the bandwidth using Carson's rule: $B_c = 2(1 + \beta_f) f_m$.

   For each value of β_f in problem 4, run the script and compare the spectrum with that obtained in problem 4. Comment on the results. In particular, what happens in problem 4 part (b)? (Hint: Look at line 6 of the MATLAB script and think of $J_0(\beta_f)$.)