HACETTEPE UNIVERSITY

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

ELE 326 TELECOMMUNICATION THEORY LABORATORY I

Deadline: May 25, 2018, 23:59 – Late submissions will not be accepted.

ASSIGNMENT

Purpose: Design and simulate an analog communication system operating on noisy channel. Observe the effect of channel noise on different modulation types.

Note: Submit your source codes with your report seperately. Use comments to explain your program code. Your report should include numerical and graphical results with your comments. Your design may require additional inputs and outputs.

Useful MATLAB Functions: fft, fftshift, fir1, filter, length, randn, wavread, hist, hilbert. You may use MATLAB help index for further information.

Following MATLAB Functions are NOT allowed: random, ammod, ssbmod, fmmod, amdemod, ssbdemod,fmdemod, mean, var, cov, xcov, corr, xcorr, power.

1. Consider the communication system characterized by the block diagram given in Figure 1. You are expected to design the blocks of this system.

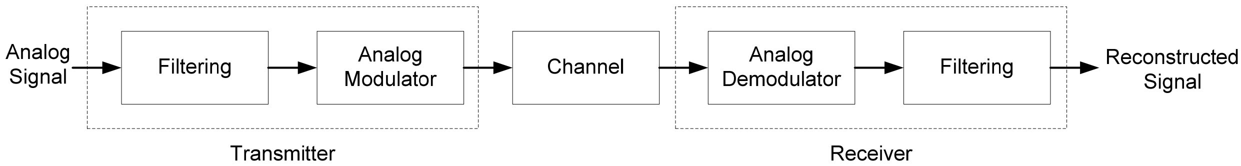

Figure 1: Block diagram of an analog communication system.

a. Design a lowpass filter "[ss]=lowpassfilter(s,fcut,fs)" which filters input signal **s** with cutoff frequency fcut and sampling frequency fs in Hertz.

b. Design a bandpass filter "[ss]=bandpassfilter(s,fcutlow,fcuthigh,fs)" which filters input signal **s** with cutoff frequencies fcutlow and fcuthigh and sampling frequency fs in Hertz.

c. Design an analog modulator "[sm]=modulation(ss,fc,mtype)" which modulates analog signal **s** to produce modulated signal **sm**. fc denotes carrier frequency. Modulation type can be selected via mtype as 'dsb', 'dsbsc', 'ssb' or 'fm'.

d. Randomly generate an additive white Gaussian noise channel vector "[w]=white_noise(N_o,sm)" whose power is N_o and has the same length with **sm**.

e. Design an analog demodulator "[sd]=demodulation(r,fc,dtype)" which demodulates noisy signal **r** to reproduce message signal **sd**. fc denotes carrier frequency. Demodulation type can be selected via dtype as 'coh', 'env' or 'pll' which stand for coherent detector, envelope detector, and phase-locked loop, respectively.

2. You are expected to simulate analog communication system in Figure 1.

a.
- Read signal “sample.wav” and obtain message signal **s**. Apply Fast Fourier Transform to message signal **s** and obtain **S**. Plot frequency spectrum.
- Filter message signal with cutoff frequency 4 kHz to obtain filtered signal **ss**. Plot filtered signal. Apply Fast Fourier Transform to filtered signal and obtain **SS**. Plot frequency spectrum.
- Modulate filtered signal with **double sideband am modulation** to obtain **sm**. Average power of modulated signal must be normalized. Transmit modulated signal through the noisy channel and obtain noisy signal **r**,

$$\mathbf{r} = \mathbf{sm} + \mathbf{w}$$

  where noise power is defined as $N_o = 1/100$.
- Demodulate noisy signal **r** to obtain **sd** using **coherent detection**. Plot the demodulated signal. Filter demodulated signal with cutoff frequency 4 kHz to obtain reconstructed signal **sr**. Plot filtered signal. Apply Fast Fourier Transform to filtered signal and obtain **SR**. Plot frequency spectrum.

b. Repeat (a) with mtype=’dsbsc’, dtype=’coh’. Compare the modulated and demodulated signals with the ones in part a.

c. Repeat (a) with mtype=’ssb’, dtype=’coh’. Compare the modulated and demodulated signals with the ones in parts a and b.

d. Repeat (a) with mtype=’dsb’, dtype=’env’. Compare the modulated and demodulated signals with the ones in part a.

e. Repeat (a) with mtype=’dsbsc’, dtype=’env’. Compare the modulated and demodulated signals with the ones in part b. Which demodulator would you prefer?

f. Repeat (a) with mtype=’ssb’, dtype=’env’. Compare the modulated and demodulated signals with the ones in parts c. Which demodulator would you prefer?

g. Repeat (a) with mtype=’fm’, dtype=’pll’.

h. Repeat (a) with mtype=’dsb’, dtype=’env’, noise power $N_o = 1$. Compare the results with part d and comment on the effect of noise.

i. Repeat (a) with mtype=’dsbsc’, dtype=’coh’, noise power $N_o = 1$. Compare the results with part b and comment on the effect of noise.

j. Repeat (a) with mtype=’fm’, dtype=’pll’, noise power $N_o = 1$. Compare the results with part g and comment on the effect of noise.

3. Read “sample2.mat” and obtain vectors **x** and **y**.

    a. Find the mean, variance, autocovariance, crosscovariance, autocorrelation, crosscorrelation, power spectral density functions of these vectors. Plot autocovariance, crosscovariance, autocorrelation, crosscorrelation, power spectral density functions seperately.

    b. Plot the pdf of the vectors **x** and **y**.

Mean of **x** $= \gamma_x = \frac{1}{N}\sum_{i=1}^{N} x_i$

Variance of **x** $= \sigma_x^2 = \frac{1}{N}\sum_{i=1}^{N} \left|x_i - \gamma_x\right|^2$

Auto-Covariance function of **x** $= c_{xx}[k] = \sum_{i=1}^{N-k+1} \left(x[i+k-1]-\gamma_x\right)\left(x[i]-\gamma_y\right)^*$, for k=1:N

Cross-Covariance function of **x** and **y** $= c_{xy}[k] = \sum_{i=1}^{N-k+1} \left(x[i+k-1]-\gamma_x\right)\left(y[i]-\gamma_y\right)^*$, for k=1:N

Auto-Correlation function of **x** $= r_{xx}[k] = \sum_{i=1}^{N-k+1} x[i+k-1]\, x^*[i]$, for k=1:N

Cross-Correlation function of **x** and **y** $= r_{xy}[k] = \sum_{i=1}^{N-k+1} x[i+k-1]\, y^*[i]$, for k=1:N

Power spectral density of **x** = ϕ_{xx} = Fourier transform of Auto-Correlation function of **x** $= FFT\left\{r_{xx}\right\}$

$$\Rightarrow \phi_{xx}(\omega) = \frac{1}{N}\sum_{k=1}^{N} r_{xx}[k]e^{-j\omega k} = \frac{1}{N}\left|\sum_{k=1}^{N} x[k]e^{-j\omega k}\right|^2, \text{ for } \omega = 0:2\pi$$