ANALOG MODULATION: AM and FM

In this homework, we will learn how to simulate AM and FM modulation/demodulation of a sampled speech signal stored in the file *speech_dft_8kHz.wav* in MATLAB. You can read this file via the command *x=audioread('speech_dft_8kHz.wav')*. This signal is sampled at 8 kHz and you can listen to it with *soundsc(x,8000)* command.

However, since you need high frequencies for modulation you have to upsample the speech signal to higher frequencies before modulating it. Then after you demodulate you have to downsample the speech to 8 kHz again to listen to it. You can use *interp()* for upsampling and *decimate()* for downsampling. You are not allowed to use modulation functions of Matlab.

(1) AM Modulation:

(a) Upsample the speech signal by 100 times. Modulate the speech signal with carrier frequency 160 kHz according to the equation:

$$y(t) = (A + m(t))cos(2\pi f_c t)$$

where $m(t)$ is the message and f_c is the carrier frequency and A is the constant chosen such that $A + m(t) \geq 0$ for all t. Plot the Fourier magnitude spectrum of $y(t)$ in dBs. Remember to label axes of the plot.

(b) Demodulate $y(t)$ using the envelope detection technique. In this method, signal is passed through a diode first and then the output is passed through an RC circuit. You can implement the ideal diode by just zeroing the negative parts of the signal. The RC circuit is equivalent to a low pass filter with the transfer function

$$h(t) = e^{-\frac{t}{\tau}}$$

where $\tau = RC$ is the time constant. You can set $\tau = 10^{-4}$. Compare the spectrum of m(t) with the demodulated signal (before downsampling). Additionally, plot m(t) and demodulated signal in the time domain. Is there any difference in the plots? If there is, why? Now downsample the demodulated signal to 8 kHz. Listen to the demodulated signal. Did you recover the speech back?

(c) Now modulate the speech signal without adding the A constant, that is,

$$y(t) = m(t)cos(2\pi f_c t)$$

Try to demodulate it with the same envelope detector. Plot m(t) and demodulated signal (before downsampling). Did you recover the speech back? If not, why?

(2) FM Modulation

(a) Upsample the speech signal by 200 times. Modulate the speech signal with $f_c = 280$ kHz and $k_f = 75000$ according to the equation

$$y(t) = cos(2\pi f_c t + k_f \int_{-\inf}^{t} m(t)dt)$$

In order to take the integral, you can use rectangular integration using *cumsum()* function. You have to divide the result of *cumsum()* by f_s. Plot the magnitude response of the modulated signal. What can you say about the bandwidth of the signal compared to AM modulation? Estimate the bandwidth of the signal with Carson's rule. Is your estimate close to what you see in the spectrum?

(b) Demodulate the FM modulated signal with superheterodyne FM receiver. Remember that for this purpose you need a differentiator followed by an envelope detector. Differentiator can be approximated by *diff()* function. Do not forget to multiply the result by F_s. Take the time constant $\tau = 10^{-3}$. Compare the spectrum of m(t) with the demodulated signal (before downsampling). Additionally, plot m(t) and demodulated signal in the time domain. Is there any difference in the plots? If there is, why? Now downsample the demodulated signal to 8 kHz. Did you recover the speech back?

Guidelines for submission

Submit your .zip file to Blackboard before 23:59 on Thursday, October 25, 2018.

Source codes and report:

(1) You should provide meaningful variable names for all your variables in your code so that we can easily understand what you are doing step by step.
(2) Please provide comments in your source codes.
(3) Reports are important. Your homeworks will be graded mostly based on your reports.
(4) Reports must integrate your results and your discussions on these. It must include your output plots with appropriate titles and your discussions (which is very important for us to decide if you understand the concepts) should refer to these plots. We do not want to read your text only report and run your code and see your output plots and relate your discussions to these external images.

File formats, naming conventions, submissions:

(1) Each question has its own .m source file.
(2) Naming for each source file must be in the form of q$questionNo$_$yourKusisUsername$.m. For example: q1_okirmemis16.m, q2_okirmemis16.m
(3) Each sub-question within a .m source file must be separated with proper lines. For example: %————- a ————-%
(4) Your reports must be in .pdf format (No .doc or .docx files).
(5) Naming for your report must be in the form of report$homeworkNo$_$yourKusisUsername$.pdf. For example: report5_okirmemis16.pdf
(6) You must put your source files and the report inside a folder named in form of hw$homeworkNo$_$your For example: hw1_okirmemis16 The folder must contain only source files and the report. It should not include the output plots, etc., as your source codes are producing those outputs and your reports are already containing those outputs.
(7) You must compress the folder in .zip format. (No .rar)
(8) Naming convention of your .zip file must be in the form of hw$homeworkNo$_$yourKusisUsername$.zi For example: hw2_kbagci.zip

Rules:

Each student must prepare MATLAB homeworks alone. Working together, sharing complete or incomplete solutions with your friends, is strictly prohibited. Students who are suspected of any such activity will be sent to the University Disciplinary Committee immediately, without any previous warning.
Remember, all Matlab homeworks MUST be submitted in order to receive a letter grade from this course. Late homeworks will be accepted to satisfy this requirement, but no credit will be given to late homeworks.
For late submissions, there will be 15 points penalty per day.