Lab 2

5ETA0 - Intro Telecommunications

March 15, 2021

NOTE: Before you start the lab, make sure you have all the correct toolboxes installed. An overview of the required toolboxes can be found in an announcement on canvas. Furthermore, exercises 2 and 3 require you to use the `designfilt` MATLAB function. Focus on the 'StopbandFrequency', 'PassbandFrequency' and 'StopbandAttenuation' variables. Make sure to use FIR filters, because they have a constant delay. An example is shown in Fig. 2, and can be obtained using `fvtool`.

Exercise 1: Raised Cosine

Download, install and open in MATLAB the application `appChapter_3_6`, the instructions on how to do this can be found on canvas.

1. Upload an integer message with a bit time T_b of 0.001 s plot the channel output without filtering it. Now turn filtering on and filter the same signal with a roll-off factor of 0.2 and plot the output again. Repeat this for r = 0.6 and r = 1 and again for a bit time of $T_b = 0.00005s$ (so 6 plots total). Compare the output of the channel for each r and T_b.
   How does the spectrum change when the roll-off factor is increased/decreased? What does the bit rate change?

2. Is it practical to make the roll-off factor as small as possible? Why or why not?

3. What are the advantages of using raised cosine signals?

Exercise 2: Filtering

Open `lab2_ex2_ex3.m`. `signal` is a gated PAM signal passed through a channel that is contaminated with low-frequency noise.

1. Plot it's PSD using `periodogram(signal, [], [], R_s, 'centered')`.
2. Try to demodulate this signal to achieve the original spectrum. This can be done by multiplying it with the appropriate frequency cosine, and applying low pass filtering, see Fig. 1. Plot `signal`, `s_c` and `s_f` to get an idea of what is happening at each stage of demodulation.

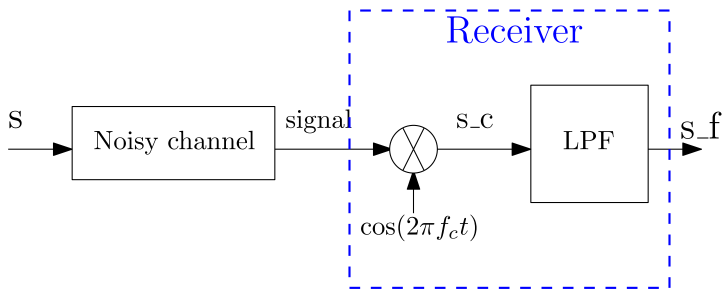


Figure 1: Block diagram of the most simple receiver circuit. This is the basis of demodulation of PAM that has been contaminated with low-frequency noise.

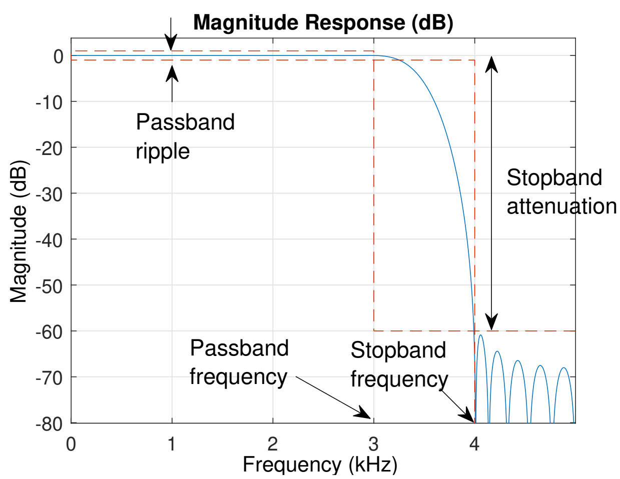
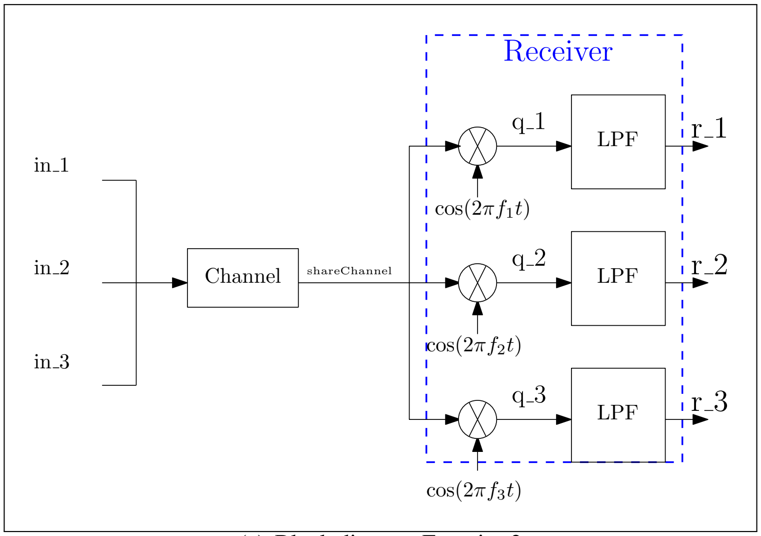


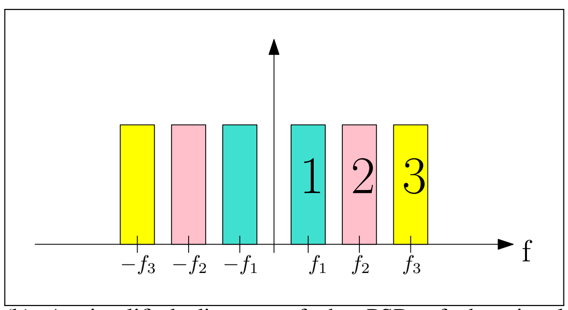
Figure 2: Filter response of filter `lpfilt = designfilt('lowpassfir', 'StopbandFrequency', 4e3,'PassbandFrequency', 3e3, 'PassbandRipple', 2, 'StopbandAttenuation', 60, 'SampleRate', 10e3, 'DesignMethod', 'kaiserwin')`, obtained using `fvtool`

Exercise 3: Demodulating and decoding line coded messages

Continue in `lab2_ex2_ex3.m`. Three messages are sent through a channel at different carrier frequencies, using different line coding, see Fig.3 (a). They have a sample rate of $R_s = 10\text{kHz}$ Load the data from `sharedChannel.mat` and plot the spectrum of the waveform using the `periodogram` function.
Note that the LPFs in the system are the same.



(a) Block diagram Exercise 2



(b) A simplified diagram of the PSD of the signal `shareChannel`

Figure 3: Diagrams for Exercise 2

1. Demodulate the carriers, as in the last exercise, by multiplying them with appropriate frequency cosines, and filtering. For the filter parameters, think of how the bit duration of the "analog" signal can be observed in the spectra, and how this relates to bandwidth.

2. What line codes are used in each case?

3. What are the messages encoded by these signals? Use the function `binaryToChar.p` provided in the exercise folder to decode the digital messages into sentences.

   The function is defined as:

   ```
   output = binaryToChar(receivedMessage, number, type)
   ```

   Here:

(a) `receivedMessage` is the message you get after low-pass filtering

(b) `number` is the number assigned to the spectra you're decoding (seen in Fig. 3(b))

(c) `type` is a string defining the type of line coding used. `type` can be equal to `'unipolarNRZ'`, `'unipolarRZ'`, `'polarNRZ'`, `'bipolarRZ'`, `'manchesterNRZ'`.

4. Change the Passband and Stopband frequencies of your low-pass filter. What is the effect on the received messages?

Exercise 4: Choosing a line code for a channel

Open `Lab2_LineCodes.m` and `Lab2_LineCoding.slx`.
You are given two channels with different spectrum properties. To test what these properties are, you will first pass a noise signal through the channels, and inspect their frequency response with the `Spectrum Analysis` block. The blocks to use are in the file and can be dragged and attached to the channel. **Blocks that give errors can be commented out using Ctrl+Shift+X**

1. What characteristics can be attributed to Channel 1?

2. What kind of line code would you use to transmit data over this channel?

Channel 2 represents a frequency band that is chosen for a certain transmission system.

3. What characteristics can be attributed to Channel 2?

4. What is the bandwidth and center frequency of the channel?

5. What is the significance of the -3dB point of a signal spectrum?

6. Channel 2 only has two voltage levels - therefore, you can **only use 1s and 0s for transmission**. Which line code(s) can you send through the channel?

7. Do you need to modulate the signal of the previous question to pass it through this channel successfully?

8. In the MATLAB (.m) file, the function `lineCode` can encode a sequence of random bits into a line code of your choosing:

   ```
   [encode,fs] = lineCode(binary, type, Tb)
   ```

   Here, `binary` is the random binary vector, `Tb` is the bit time, and `type` is the chosen line code as a string.

   Line codes can be chosen from `'unipolarNRZ'`, `'polarNRZ'`, `'unipolarRZ'`, `'bipolarRZ'` and `'manchesterNRZ'`.

   (a) For Channel 1, choose a line code you specified in question 2. What bit time T_b should you choose?

   (b) `encode` is now your up-sampled, line coded bit sequence. You can now use the `Signal From Workspace` block in the Simulink model to pass the signal through the channel. If you use the carrier signal, make sure to specify the carrier frequency, `Fc`, for the sine wave in the `Multiplication with carrier` block.
   Inspect the spectrum at the output of the channel and compare with the input spectrum.

      i. What is the SNR of this channel?
      ii. What is the attenuation of this channel?
      iii. Could the signal be restored without information loss?

   (c) For Channel 2, choose a line code you specified in question 5. What bit time T_b should you chose?

   (d) Repeat steps i-iii as in (b), but this time for Channel 2.

Appendix

MATLAB function	**Description**
`t`	Vector representation of time
`r = randi([min(r) max(r)], rows, columns)`	Returns an array of dimensions `rows x columns` composed of integers drawn from the interval [imin,imax].