LABORATORY PART

In the laboratory part we transmit a QPSK/RRC signal through a radio channel simulator and sample the simulator output using AD cards. The sampled data is transferred to MATLAB. You should design and implement a receiver that estimates the channel impulse response, removes intersymbol interference (ISI) from the signal, and demodulates the data.

You can locate your files in the special directory assistant will create for you. Into this directory assistant will copy also the transmitter and receiver templates.

Step 1: Create the transmitted signal and download it to AWG

The structure of a possible transmitter is given in the file TransmitterBasicCode.m. The file will be in the directory that assistant will create for your group.

The transmitter should send over the channel the message located in the file input_lab2_L1.mat. You have to load these symbols into Matlab, convert symbols to the bits, modulate, oversample and rrc filter the modulated symbols.

The template file helps you to: map the bits to 4-ary symbols by using the function `bits2sym`. Add the training symbols to the beginning of the data block (Figure 1) and create the transmitted signal in MATLAB by using QPSK modulation and RRC signaling. Use eight samples per symbol. Save the real and imaginary part of the transmitted signal vector to separately under different names (rrc_real and rrc_imag).

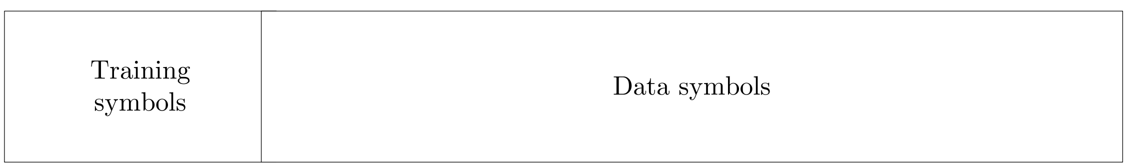

Figure 1. The data format.

Step 2: Sending data over the channel

The modulated and filtered symbols are send over the channel simulator. For that first the bits are submitted to a National Instrument D/A board that converts the signal to analogue form. This analogue signal is provided to the channel simulator baseband input. The baseband output is connected to the A/D converter that samples the signal. The sampled signal is load to Matlab workspace. For maintaining the synchronization between the transmitter and receiver both of them are started from a trigger signal. The trigger signal should be in order of 10 Hz or lower. At each trigger instant the transmitter sends one copy of the signal.

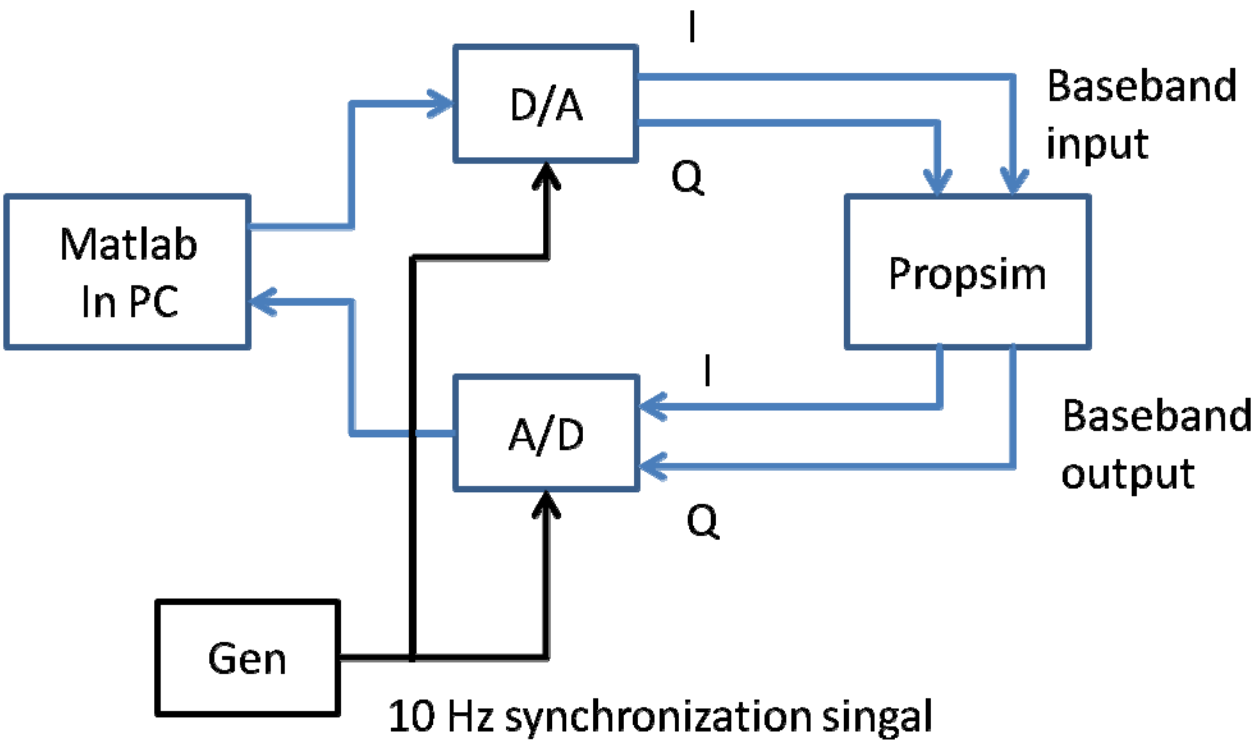

Figure 2. Measurement set-up.

Transmission and reception is controlled by the script SendDataOverChannel.m. this file should be in your Matlab path. For using it, it is sufficient to uncomment the corresponding line in the “Transmitter” template file.

Running the script captures the complex channel output into two vectors that you should save for further processing.

In this laboratory work we investigate how different channels impact the equalizer performance. For that you have to select the below mentioned channels and to send the created signal over them. For each channel save the measured samples for further processing.

Choose in the simulator channel models given below; What is the absolute delay spread of the channels? In theory, how many taps do you need in your channel estimate?

Once you have obtained the received signal, you may proceed to the post-laboratory part. If you have time you can start implementing the receiver in the student laboratory, and ask questions from the assistant.

Run the measurements with the following channels:

Lab2-1tap-const

Lab2-2tap-const

Lab2-3tap-const

Lab2-5tap-const

Lab2-3tap-const-rndph

Lab2-4tapconstfract

For the following channels make the measurements for two different user speed 3 and 10 km/h.

Lab2-2taprayl

Lab2-3taprayl

Lab2-5taprayl

Step 3: Implement the receiver and detect the transmitted symbols

Implement the receiver shown in Figure 3 and detect the transmitted symbols. You may expand the script `t_ser.m` you implemented in the preliminary problems.

A template that helps to structure your receiver is given in the script ReceiverbasicCode.m

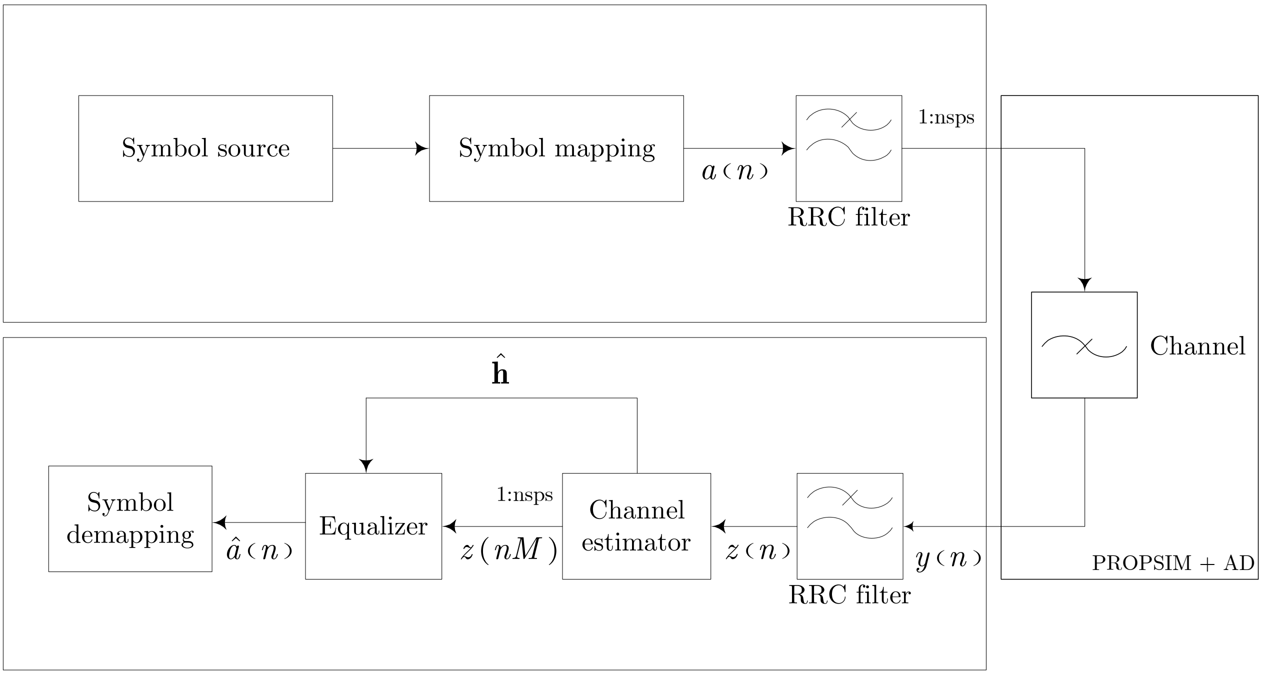

Figure 3. Block diagram of the communication chain.

Notes:

- RRC filter: Nothing strange here.
- Channel estimator: This block has two inter-related purposes: it has to supply a channel estimate $\hat{\mathbf{h}}$ to the equalizer, and it has to reduce the sampling rate of $z(n)$ to a single sample per symbol, since the equalizer works on that sampling rate. A heuristic procedure for accomplishing this is suggested below. You may figure out a better way of doing this.

Assume that $\text{nsps} = M$. Demultiplex the signal $z(n)$ to M sequences with nsps=1 in each (sampling at symbol rate in each). You can now use the estimator function you implemented in the preliminary part to each of the M subsequences separately. You will end up with M estimates $\hat{\mathbf{h}}_i$, $i = 1, 2, \ldots, M$.

- Symbol demapping: You can map the symbols back to bits with `bits2ascPrint.m`. At some point in the receiver chain you will have to remove the training sequence from the signal. You may do this after or before symbol demapping. The code that does such mapping is included into receiver template.

Questions:

Analyze results

Make the following analysis for each measured channel for the first sampling sequence $z(n), n = 1$.

1. Estimate a channel response for all measured channels. Set the channel estimator length to 5. Report the lengths as a table: name of the channel versus the tap values.

2. Calculate the ISI for all the measured channels for the channel estimator length 5 and equalizer length 7. Report the results as a table: name of the channel versus the ISI.

3. Decode all the data sequence for all the channels. The transmitted data sequence is in the file input_Lab2_L1.mat. You can use this sequence as a correct reference sequence. Make the table describing the errors in different channels. Calculate the error for the binary bits. (This is the received sequence before converting it to ASCII text.)

4. Comment how different channels impact the equalization.

   - Impact of the channel taps.

   - Impact of the fading as a function of the user speed.

Make the following analyze only for the measurements with the channels: lab2_4tap_constfract, lab2_5tap_const.

In the following two questions use only the first sampled sequence $z(n), n = 1$.

6. Plot the system impulse response, i.e. the convolution of the channel response and the equalizer response. Repeat for a few different equalizer lengths and two different channel estimate lengths. (For example, estimator lengths 5,7,9 and equalizer lengths 5 9 21).

7. Compute the ISI. Give the ISI values in a table form: name of the channel versus the parameters of the estimator and equalizer. What is the optimal combination of channel estimate length and equalizer length? (Select all combinations of following parameters. Estimator length: 3, 5, 7; equalizer length: 3, 7, 9, 21)

Make the following analysis for each sampling instance $z\ n\ , n\ \ 1 \ldots nsps$.

8. Compute the ISI energy for each sampling instant using the optimum length equalizer and channel estimate computed in the task 7.

9. Plot the frequency response of the channel, equalizer and the system for the optimum equalizer length, channel estimate length and sampling instant for the sampling instants: 1 3 5.

Instructions for the lab report

In the first page of the lab report include your name student number and email address (for sending boomerang info). You should write the laboratory report with a word processor. There are no strict requirements on the format of the report, except that it must be readable and understandable. Anyone reading your report should be able to follow your line of reasoning and, if necessary, be able to repeat your actions and verify the results. To make the report more readable you should embed figures, tables etc to your report (not everything to appendices). Long MATLAB scripts and functions should be put into appendices.

For plotting figures, excellent black&white printing quality is obtained by using the command `print picname -deps2 -tiff`. The EPS picture file can be inserted into the document and resized according to one's needs without degradation in quality. Use `subplot` when applicable.

The report does not have to be long but you should include at least:

- A summary of your receiver implementation, including a short description of the MATLAB files.
- Answers to the questions presented above along with the appropriate figures.