Laboratory Demo 2: Implementing a QPSK wireless link

EE161: Digital Communication Systems
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1 Introduction

The purpose of this experiment is to evaluate the performance of a wireless link implemented with ADALM-PLUTO radios and MATLAB Simulink models. Mapping is QPSK and pulses are square-root raised-cosine (SRRC). The effects that changes in the receiver gain and rolloff factor have on the spectral density and the bit-error rate (BER) are measured experimentally and analyzed.

You will need to download the following MATLAB Simulink models below from Canvas directory `Files/Radio Experiments/Demo 2`.

```
plutoradioQPSK_Tx_test_2020.slx
plutoradioQPSK_Rx_test_2020.slx
```

Download also `MAT` file `QPSK_radio_parameters.mat`. Before you run each model you need to enter the command below in the command window:

```
load QPSK_radio_parameters.mat
```

2 Link parameters

The default main parameters of the link are as follows:

- <u>Software-Radio QPSK transmitter</u>
  - SRRC filter rolloff factor, `alpha = 1/2` (default)
  - Transmitter radio gain, `Gt = -5` dB (default)
- <u>Software-Radio QPSK receiver</u>
  - SRRC filter rolloff factor, `alpha = 1/2` (default)
  - Receiver radio gain, `Gr = 25` dB (default)

For the report, find the values of length and number of samples per symbol of the SRRC filter as well the bit rate of the link.

Important: Before starting this experiment, disconnect and then reconnect the min USB cable from both radios. This will reset the radios. After you finish all measurements, repeat the procedure: Disconnecting and then reconnecting the min USB cable from both radios.

Never connect two antenna ports directly using a cable. This will irreparably damage the radios.

Important: There is always a frequency error Δf between the center frequencies of the two radios. A the receiver,you need to add or subtract a few kHz to the center frequency until the received spectrum is properly centered. As an example to increase the center frequency by 1 kHz, stop the radios and type `fc = VALUE + 1e3;` in the command window at the receiver. Change center frequency values until you get the received matched filter values forming four clouds. Each time you change the center frequency, you need to stop and restart the model at the receiver.

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3 Sensitivity to receiver gain

Since the wireless link implemented in this experiment transmits signals over the 915-MHz license-free ISM band. As a result, a certain amount of interference will be experienced. Keep this in mind when analyzing the experimental results. You must make sure that the center frequency `fc` is set up properly by typing `fc = VALUE;` in the command window, where `VALUE` is given by the instructor. This is needed to ensure that the radio pairs of wireless links do not use the same frequency range to avoid interference.

Important: When you run the link models, make sure that there is a line of sight between the antennas at the transmitter and the antennas at the receiver free of obstacles (people). In addition, while you are running the models, make sure that no one moves. The link is very sensitive to reflections on people around the radios.

3.1 Receiver gain equal to 25 dB (default value)

3.1.1 Transmitter

Open the QPSK transmitter radio model `plutoradioQPSK_Tx_test.slx` in one of the desktop computers (first student).

3.1.2 Receiver

Open the QPSK receiver model `plutoradioQPSK_Rx_test.slx` on the other desktop computer (second student). Wait for the transmitter model to run. Then start the receiver model and wait until it stops. This will take a couple of minutes in order to receive approximately 10 million bits.

Capture or sketch the received spectrum, the constellation before and the constellation after correction. These appear in three figures. Attach the captures to your report. You may need to press the "scale" button in a window to see the full range of a plot. Take note also of the BER value (this is the top of the three numbers in the `BER Display`).

In the unlikely event that you get a high BER value (close to 0.5), try stop and restart the model. If that does not work, then try adding or subtracting in 500 Hz steps to the center *frequency* `fc` *As a last resort, increase the receiver gain by 5 dB at a time until you get a relatively low BER value. .*

3.2 Receiver gain set to other values

Repeat the procedure in section 3.1 above with the receiver gain set as follows. Denote the receiver gain used in section 3.1 by `Grinit = 25` (or a higher value if this was needed). The receiver gain shall be set equal to each of the following values:

```
>> Gr = Grinit-20;
>> Gr = Grinit-15;
>> Gr = Grinit-5;
>> Gr = Grinit+10;
```

For each receiver gain value, capture the spectral density of the received signal, the constellation plots, and BER.

4 Sensitivity to rolloff factor α

Repeat the procedure in section 3.1 with the receiver gain set back to 25 dB (or back to the value that gave a low BER) and the rolloff factor modified to each of the following values:

```
>> alpha = 0.1;
>> alpha = 1;
```

For the report: What is the effect of the rolloff factor on the received spectrum? on the BER?

5 Performance analysis

The procedures in this section are to be done **after the experimental measurements are taken**. Attach the plots to your report.

5.1 Receiver gain vs. BER

Plot the receiver gain `Gr` (dB) versus BER in a semi-logarithmic graph.

5.2 SNR vs BER

For each of the receiver gain values in section 3, use the received spectral density (Spectrum Analyzer window) to estimate the SNR (dB) as the difference between the flat portion of the raised-cosine spectrum and the error floor. Then plot the estimated SNR (dB) versus BER in a semi-logarithmic graph. How does it compare to theory?

5.3 Receiver gain vs. constellation

Analyze the effect that the receiver gain has on the corrected constellation points at the receiver. (These are shown in the "After Carrier Synchronizer" window.)