Lab 3: Transmission through SDR

5ETA0 - Intro Telecommunications 2023/2024

Read the following instructions carefully before starting with the Lab.

Throughout this Lab, you will be using the ADALM-PLUTO SDR for the wireless transmission of data. Before you can start the Lab you need to reserve an SDR group. Each group contains 3 SDRs. There are 27 groups (81 SDRs in total). Therefore we encourage you to work in student teams consisting of 3 students.

Per team, you place one reservation per timeslot only!!!

You place your reservation via the following URL:
https://remoteradio.ele.tue.nl
Note: First, select a date, then select a timeslot. Each timeslot has a duration of one hour. If you want to use the same SDR group for a longer time, please make certain to reserve it for multiple timeslots. The maximum amount of time slot reservations per day is 4.

After you place your reservation you receive an email with the SDR device numbers that are part of your SDR group. If you have not received an email ask one of the TA's to inform you about the device numbers.

Now you can connect with the SDR devices. Use the link from the email or follow the following scheme:
https://remoteradio.ele.tue.nl/device/<devicenumber>/

Note: you need to enter the URL with a "/" at the end
For example, if you want to connect to SDR device 2 the URL would be
https://remoteradio.ele.tue.nl/device/2/

To sign in you use the email address that you used for the registration and the password that you received via email! The password does not end with a "."

Note: If you entered the wrong password you probably need to clean your browser history.

Every member of the team can use the login data to sign into one of the 3 SDRs. During the lab, you will use one SDR as a transmitter and another one as a receiver. You can access both SDR devices (Tx and RX) by using different tabs within your browser or you use different physical devices (PCs, Laptops, Smartphones).

Some general guidelines regarding the use of the SDRs:

1. Always start the receiver before the transmitter.
2. Sometimes the automatic playback won't work. This is not because you demolished the SDR, but this happens sometimes due to the web application.
3. You have to change the centre frequency to 2400 MHz + "SDR group number in MHz". For example, if you use SDR group number 2 your centre frequency is 2400+2 MHz = 2402 MHz

Some questions are not practical but they are in the lab to reflect on your own findings.

Exercise 1: Analog transmission AM & FM

The first exercise will concentrate on the AM analog transmission. The analog transmission is done through the SDR. Since this is an online environment it will never be real analog transmission, and it will only ‘pretend’ to be analog transmission. The signal is stored with 8 bits per sample, due to the calculation power of the SDR. Therefore there are only 256 levels to which the signal can be mapped (think about the quantizing exercise of lab 1). When the gain is high enough it will imitate an analog signal better than with a low gain.

Transmit one of the song.wav files over the SDR in AM mode with the default settings (values that are already present when you open the web application). First use the two numbers of the assigned SDR’s closest to each other.

1. What do you hear? What happened to the signal while being transmitted over the SDR? (Compare it with the original sound, provided on Canvas)
2. Plot the Power Spectral Density plot in MATLAB using periodogram(signal, [], [], fs, ’centered’). What does the plot show you? Could it explain what you hear? (Hint: You can load the signal using [wav, fs] = audioread("song1.wav").)
3. How many dB is lost while transmitting through the SDR at this default settings?
4. Plot amplitude of the obtained signal against amplitude the original signal. What do you see? Can you explain this? (Hint: look at the gain)
5. Try to find a values for the variables for which the SDR has a better spectral output. (Hint: use the ‘sample maximum: x.xxxx’ in the console of the analog receiver to find these values. The sample maximum is related to the gain.)
6. Listen to the sound and compare the signals in MATLAB. Compare the Power Spectral Density as well as the amplitude. Think about the delay when you plot the amplitude plot (hint: look at the data and the starting point of the transmission).
7. Try those values for the device with the numbers furthest from each other. What do you observe?
8. Find the correct values for those devices and try them on the devices with the numbers closest to each other. What do you hear? Can it be explained by the PSD plot?
9. Try the same values for FM transmission as you did for AM transmission (change the SDR from AM to FM). Do you hear a difference?

Exercise 2: Simulink digital data Transmission

1. You will transmit a waveform through a simulation of a noisy channel. In analog transmission, the time taken to transmit a waveform is the time of the audio file being transmitted. You will inspect the effect of levels on digital transmission time.

   You are given several audio files to choose from. You can also upload your own (preferably encoded in unsigned 8 bit integers, with a sample rate of 8000kbps).

   (a) Transmit a chosen audio file with QAM4 as follows:

      i. Open Lab3 DigitalModulation.m.

      ii. Run the 1st section of the code. This uploads the audio file to your MATLAB workspace.

      iii. Run the 2nd section of the code. Choose the appropriate amount of bits for a 4- level channel (QAM4). binary is the vector that you will be transmitting through the noisy channel.

         binary = audioToBinary(wav, bits)

      iv. Open Lab3 DigitalModulation.slx

      v. Inspect the model. The binary is modulated with QAM, sent through a noisy channel, and decoded before the output. Some useful measurements are given.

      vi. Double Click the Rectangular QAM Modulation block. Choose the ”M- ary number”, which represents the number of levels in the system. As you click ”Apply”, you will be able to see what the constellation diagram of the levels looks like in the complex plane by ”View Constellation”.

      vii. Repeat the same step for the demodulator block placed after the channel.

      viii. In the Output box, choose an appropriate output name for your received data (e.g. out.qam4). You can do this by double-clicking the ”To Workspace” block.

      ix. Press Run (Ctrl+T), and wait. This will take a while, so be patient. The simulation will be finished once the full message is transmitted.

      x. Once the simulation is done, note down the BER and the time spent transmitting.

      xi. Repeat all previous steps for QAM8. QAM16, QAM32, QAM64, QAM128 and QAM256.

   (b) Plot the transmission time against levels with MATLAB in section 3. What happens to the transmission time as levels increase?

   (c) What trends can you see with increasing levels? How does the transmission time compare to analog transmission?

Exercise 3: Digital transmission

For this question, use the SDR's closest to each other, and let the transmission power be the same. Also compare the signal in the receiver window to the signal you send.

1. Draw a (simple) block diagram of the digital transmission system as described in the SDR webpage. Make sure to incorporate both the inner and outer FEC and a general modulation block.
2. Read https://en.wikipedia.org/wiki/Error correction code to understand how FEC works.
3. Try the different FEC's and listen to the differences.
4. Try to transmit a song with different levels of QAM. Compare your results with the results of Exercise 3, is it the same or not? Can you also hear the difference and is this explainable with the values you got for among other things the BER?
5. What phenomenon do you hear when you use digital transmission?
6. Give the three best (with the lowest error) modulation formats out of DPSK16, ASK16, QAM16, APSK16, BPSK, OOK, ARB16OPT, QPSK.