# CS-330 Assignment 4
# Modulation, Channel Impairments

**Deadline:** 12/11/2023 23:59 via turnin

2 November 2023

## General Information

The goal of this assignment is to become familiar with different modulation schemes, the impact of noise and frequency offset, as well as pulse shaping.

## Exercise 1

In this exercise you will introduce noise and frequency offset to your signal.

- Create a flowgraph with the name *lab4_1.grc*
- Assume a sampling rate of 50 kHz and a test cosine signal at 1 kHz.
- **Add** some gaussian noise with the *Noise Source* block. Use a QT Range slider from 0 up to 1 to adjust the amplitude in real time.
- **Multiply** the original signal with another signal. Use a QT Range slider from 0 up to 10KHz to adjust the frequency of the second signal source in real time.
- Use a frequency sink to visually inspect and compare the 3 signals. 📻

What do you observe? Report how each one of the impairments (noise, CFO) affects the signal. 📻

## Exercise 2

This exercise is the same as the previous one, only this time you will use a vector source instead of a signal source. You will use the **lab4_2.grc** flowgraph, which is incomplete so you will need to perform some modifications and add a few blocks.

1. You are given a vector with values, again you will **add** some noise to them. The noise source is a stream so you will need to convert it to a vector to add it to your original vector, and then convert it back to a stream to inspect it in the constellation sink! 📻

Again report how the constellation points are affected from the noise!

## Exercise 3

This exercise will help you to get familiar with the modulation and constellation, as well as the impairments of noise and Carrier Frequency Offset (CFO). For this assignment you will use the **lab4_3.grc** flowgraph.

1. The *lab4_3.grc* flowgraph uses a BPSK modulation that maps data into constellation points. There are two sliders. The first controls the amplitude of noise, whereas the second inserts a Carrier Frequency Offset (CFO) at the system. Note that CFO is a

common hardware impairment between the TX and RX device and telecommunication standards should always deal with it. Play with the sliders by adjusting their values and **report** what you observe. How each one of the impairment (noise, CFO) affects the constellation points?

2. Modify properly the flowgraph in order to support other modulations schemes too. More precisely the flowgraph should support:

   - BPSK
   - QPSK
   - 16QAM
   - 64QAM

   The constellation point mappings are depicted at Figures 1-4.

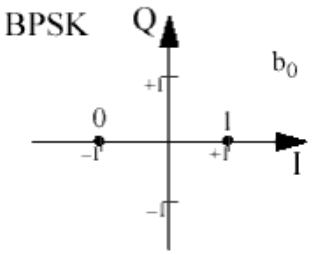


Figure 1: BPSK constellation points

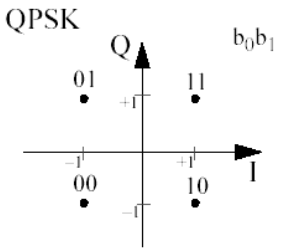


Figure 2: QPSK constellation points

3. You may observe that the maximum IQ amplitude of each modulation scheme is different. This means that the mean energy of each modulation scheme is different. In general this is not desirable. For this reason, perform normalization at the constellation points of each modulation scheme. The normalization factors can be retrieved from the table below. Report a screenshot for each one of the modulations.

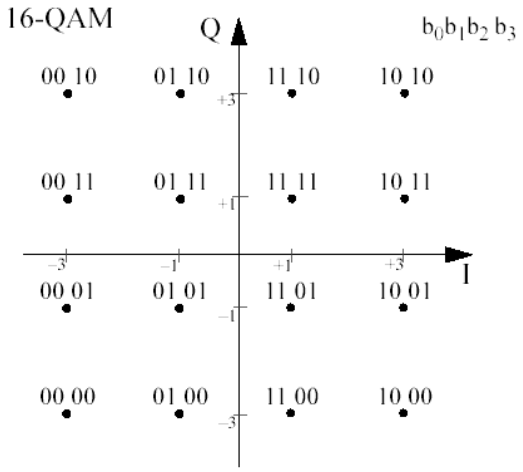


Figure 3: 16-QAM constellation points

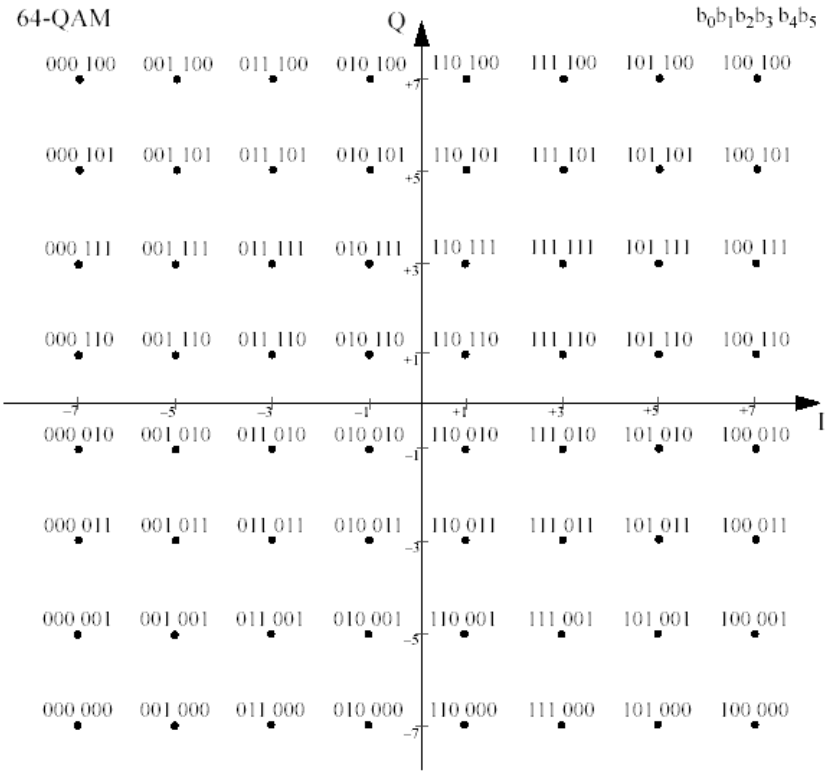


Figure 4: 64-QAM constellation points

| Modulation | Normalization factor |
|---|---|
| BPSK | 1 |
| QPSK | $1/\sqrt{2}$ |
| 16-QAM | $1/\sqrt{10}$ |
| 64-QAM | $1/\sqrt{42}$ |

4. For each one of the modulations report the maximum possible noise amplitude that can be achieved without errors. Actually without a demodulator this value can not be precise. Just provide an empirical estimation. Compare your findings and provide a brief explanation.

5. Do the same for the CFO. How each of the modulations is affected. Is there any similarity with the previous task or not? Discuss.

## Exercise 4

Alter the flowgraph of the previous task, in order to support 8-PSK modulation too.

1. Assuming that one of the constellation points is the $(1 + 0j)$ find the others. How did you compute the coordinates of the rest of the constellation points?

2. Provide a screenshot with the constellation.

3. Compare the 8-PSK with the QPSK, regarding the immunity in noise and CFO.

4. Compare the spectrum of 8-PSK and 16-QAM. What do you observe?

## Exercise 5

In this exercise you will investigate the Frequency Shift Modulation (FSK). For this assignment you will use the *lab4_5.grc* flowgraph. This simulation is quite similar with the PSK case. The Frequency Sink provides a graphical view of the transmitted signal, whereas the Time Sink provides a view of the bit stream after the demodulation.

1. Try different values of noise and CFO and compare your findings with the BPSK. Is the FSK more resilient to noise and CFO? **Discuss!**

2. Search through the literature and report your findings about the *Modulation Index* and *Deviation* parameters and how they are used in FSK.

3. How the CFO affects the FSK modulation?

4. Using existing blocks, try to recover from the CFO effect.

**About Submission**

The submission of the Assignments will be done through the **turnin** process. If needed, more info will be sent to the list prior to the deadline. You can turnin this assignment until **Sunday 12/11 23:59**. Use the command below:
**turnin assignment4@hy330 <dir>**

You should provide a report as a **single pdf file**, containing your comments, screenshots or anything that you believe will be helpful for your grading. Also include any .grc files that you have created or changed.

**About Oral Examination**

All the students who have submitted their exercises are requested to attend the oral exam session, in order to present their solutions. A short quiz will also take place during that time. You will need to choose a timeslot for the oral exam using Doodle. More details will be sent to you via email.

**Attention**

- Each student will only be examined during the timeslot choosed.
- During this session both the Assignments 4 and 5 will be examined.
- Both the timely submission and the oral exam session will contribute to the grading of the assignment.