Alexandria University
Faculty of Engineering
Electrical and Electronics Engineering Department
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جامعة الإسكندرية
كلية الهندسة
قسم الهندسة الكهربية
الفصل الدراسى الأول, 2023/2022

DIGITAL COMMUNICATIONS LAB

Project

In the Digital Communications project, you will investigate the performance of an OFDM-based communication system.

About the project

The digital communications lab project is a group-based project, in which a group of students collaborate in completing the different aspects of the project. The task of the project is to build a semi-complete communication system based on OFDM, therefore it consists of building multiple separate communication blocks that work in sequence. Each group of students should consist of 6-10 students (these limits are hard limits; no exceptions allowed). Each group would study the mentioned topics and provide the required outcomes for each of the parts as instructed below in this document.

Goals and grading of the project

The goal of the project is to assess different important skills that a student should have. These aspects include

- **To learn new topics that are not necessarily covered (at all or in great depth) in class.** Therefore, the project consists of different topics that the student should be able to follow and cover via self-learning and investigations.
- **To assess the performance of the solutions that the student comes up with for problems related to digital communications.** This should be done by using the same BER simulation techniques that were presented in previous labs.
- **To demonstrate their findings effectively and clearly.** This is covered by allowing groups of students to present their results and findings in a presentation.

Since this is a group project, students are advised to be careful when forming their respective teams, taking into account the aspects mentioned above. It would be a good strategy to distribute the work among the students in the group according to what they do best. From that perspective, project grading will not distinguish much between individuals in the same group. Therefore, it is perfectly okay (and in fact expected) for some students in a group to entirely work on presenting the findings of the group; other students focus on research aspects; others focus on coding aspects and so on.

Due to the open-ended nature of the project, there are not going to be detailed instructions for finishing the project. Expect that you will need to think a bit about how to complete the project; you can find the hint below helpful in this regard.

Regarding aspects which require coding, please feel free to use any coding language that you may feel comfortable with. However, it is recommended to use MATLAB which is better suited to handle digital communication-related simulations.

Project submission

The outcomes of the project should consist of the following:

- Presentation slides which describe the results and findings of the group for each aspect of the project
- The codes used to generate the results of the project

Each group will present their findings to the instructor(s) in week 14 of the semester. The details of these presentations will be announced at a later time. For now, you can prepare your presentations assuming that the total presentation time for each group will be 20 mins, with 10 mins for discussions.

Collaborations between students and cheating

Each group of students is allowed to fully collaborate among themselves in discussing topics and writing codes. However, collaboration between groups is **only allowed as follows:**

- Students **can** discuss concepts and ideas related to the aspects they are studying in the project
- Students **cannot** share or discuss codes

Any sharing of codes (full codes or even parts of codes) will be considered as cheating, and the grades will be severely deducted from all collaborating groups.

Note that you have to implement all the required codes on your own. You cannot use built-in MATLAB functions. You cannot also find existing codes which do the tasks required in the project. **Using existing codes is considered as a form of cheating and will also be severely penalized**. You can safely assume that, if you find a code online that does the job, chances are the instructors are aware of it as well!

Helpful hint

This will be an above average project, so expect that it will require a lot of work. Please ask any of the professors and instructors for help whenever you are stuck in something or something is not clear. The instructors will try to help as much as possible.

No question is a dumb question, even if you are stuck with a MATLAB error that you cannot resolve. The only rule in asking a question is that you do your best finding the answer before you come with the question.

It would be much more appreciated by the instructors if you ask them many times for help as you take your project to completion, rather than remain struggling during the entire time until the project submission day and end up with very little to show.

Project details

A typical baseband OFDM-based transmitter is depicted in Figure 1, which consists of the following major processing blocks:

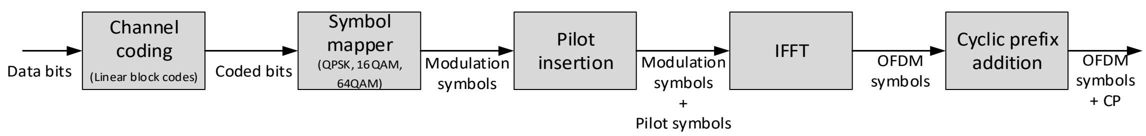

Figure 1 An OFDM-based transmitter.

1. <u>Channel coding:</u>
   The channel coding block takes as input the raw data bits that is targeted for communication. It performs a coding operation which produces a corresponding set of coded bits. The goal of channel coding is to help combat some of the impairments that arise from the communication channel. Examples of codes that can be applied here are: linear block codes, convolutional codes, turbo codes, LDPC codes, polar codes, etc. For example a (7,4) linear block code takes an input of 4-bit block and map it into a 7-bit codeword by multiplying by a 7×4 generator matrix
2. <u>Symbol mapper:</u>
   The symbol mapper takes the coded bits and produces a corresponding set of modulation symbols according to the modulation technique used, e.g., QPSK, 16 QAM, 64 QAM, etc. Note that symbol mapper outputs the lowpass equivalent of the transmitted signal, e.g., for the QPSK, the output is $\frac{1}{sqrt(2)} * \{1 + j,\ 1 - j, -1 - j, -1 + j\}$
3. <u>Pilot insertion:</u>
   In order to help determine the channel for necessary channel equalization at the receiver (and optionally the transmitter), pilot symbols are inserted among the set of generated modulation symbols. The pilots are known symbols that the transmitter and the receiver agree on. For example, the transmitter and the receiver may agree that the pilot modulation symbol is $3 + 3j$, and agree on sending the first OFDM symbol (all subcarriers) such that every subcarrier carries the pilot modulation symbol. These fixed symbols do not carry information and the receiver uses it only for channel estimation, etc.
4. <u>IFFT:</u>

The set of modulation symbols and pilot symbols are passed to an IFFT block to perform the necessary OFDM-based modulation, and the output of the IFFT block is a sequence of OFDM symbols.

5. Cyclic prefix insertion:
   The set of OFDM symbols are prefixed with a CP to facilitate channel equalization and prevent Inter-Symbol Interference (ISI).

We consider a corresponding OFDM-based receiver as shown in Figure 2. As you can tell, the details of the receiver is not shown; you will need to determine a suitable receiver that works with the transmitter shown above.

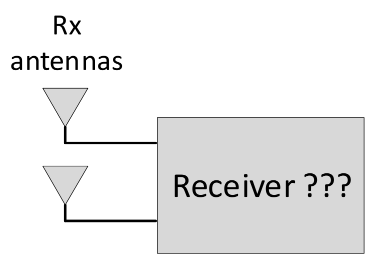

Figure 2 An OFDM-based receiver.

Task 1:

Determine the receiver structure which is expected to work with the transmitter in Figure 1. You would need to think about the different operations performed in the transmitter and see what you need to do about them in the receiver *and* in which order.

As you can see in the receiver, it is depicted to have two receive antennas, while the transmitter is assumed to have one. In fact, we will consider the following scenarios in our project: 1) 1x1 SISO setup, 2) 1x2 SIMO setup.

The main goal of this project is to assess the performance of this OFDM transceiver in the presence of different communication channels. We consider two different channels in this project.

1. Additive White Gaussian Noise (AWGN) channel:
   We consider an AWGN channel with a noise variance equal to $N_o/2$. The value of N_0 should be calculated according the E_b/N_0 value.

2. Multi-path fading channel:
   We consider a multi-path fading channel which is modeled as an L-tap discrete filter $h[n], n = 0, \ldots, L-1$. The coefficients of the filter taps are each generated as Complex Gaussian random variables with zero mean and variance 1 (what would be the distribution of the magnitude of these coefficients?). Specifically, we can generate this channel according to the following equation:

$$\boldsymbol{h} = \frac{1}{\sqrt{2L}}[randn(1, L) + 1i * randn(1, L)]$$

We know that an estimation of the channel coefficients is needed at least at the receiver side for this communication system to work well. We therefore propose two variations of this channel in our study

a. A deterministic fading channel realization: in this variation, the channel realization is fixed for the entire run of your simulation
b. (Optional) A fading channel with a coherence time τ: in this variation, the channel realization is maintained constant for a duration of τ OFDM symbols; this duration is called the *coherence time* of the channel. In this setting, you would need to account for the fact that the channel estimation that you obtain is only valid for the duration of the coherence time.

Target:

Generate probability of error (P_e) curves against signal-to-noise ratio (E_b/N_o) for different modulation schemes and under different MIMO setups. The expected outcome is a set of probability of error curves for each selection of modulation/MIMO/channel choice from the lists below.

Modulation schemes:

- **QPSK**
- **16 QAM**
- **64 QAM**

MIMO setups:

- **1x1 SISO**
- **1x2 SIMO**

Channel models:

- **AWGN**
- **Multi-path fading channel with fixed realization**
- **(Optional) Multi-path fading channel with a coherence time τ.**

What you should end up with is a set of $3 \times 2 \times 2 = 12$ performance curves, where each curve correspond to a selection of modulation/MIMO/channel model. For example, you should have a curve corresponding to using QPSK in a 1x1 SISO setup and AWGN channel, another curve for QPSK in a 1x1 SISO setup and deterministic fading channel and so on. In case you want to use the optional multi-path fading channel with a coherence time τ, then you would generate $3 \times 2 \times 3 = 18$ curves. In all these simulations, the parameters to use in your simulation are shown in Table 1.

No. of simulation runs	1000 Frame per E_b/N_0 value
E_b/N_0 values	[0:3:40] dB
No. of OFDM symbols per run	100

FFT size	1024
Fading channel delay L	50
Coherence time τ	10

Table 1 Simulation parameters.

Contact us if you have questions

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