# Fourth Year Communications Report
# 2025-2026

**Due date:** 20 Dec 2025.

***General notes:***

- It is always a healthy practice to organize your code, comment it, and write the parts that are repeated a lot in a function and call it when needed.
- Make your graphs clear.
- Only hard copy submissions are accepted.
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- **You must submit you a single code file, not multiple files.**
- **AI Tools are not allowed in your code.**
- **You can use AI Tooles only in your reports to rephase or for grammar correction.**
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- **Maximum 3 students per group.**
- **You will be evaluated based on the discussion performed by the TA.**
- **<u>If any parts of 2 reports were found similar, both reports will be given zero grade.</u>**

GOOD LUCK!

## Problem 1: Execution time of DFT and FFT

In this section, it is required to compare between the execution time of Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT).

a. Write MATLAB function to implement DFT according to

$$X(k) = \sum_{n=0}^{N-1} x(n)\, e^{\frac{-j2\pi nk}{N}} \quad 0 \le k \le N-1$$

b. Generate random test signal $x_i(n)$ of length $L = 4096$, then use $tic$ and $toc$ commands in MATLAB to compute the execution time of DFT $\{x_i(n)\}$ using the function developed in part a. and the execution time of FFT $\{x_i(n)\}$ using the built-in MATLAB function FFT( ).

c. Identify which of the investigated transform implementations offers superior performance with respect to the execution time.

## Problem 2: Bit-error rate performance for BPSK and 16-QAM over Rayleigh flat fading channel

In this section it is required to simulate the Bit-Error Rate (BER) performance of BPSK when transmitting over Rayleigh flat fading channel. The system model for BPSK is shown in Fig. 1

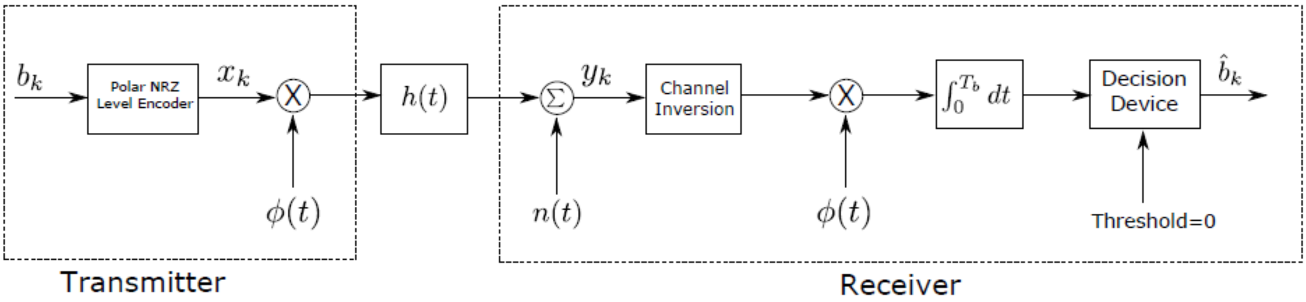



**Figure 1:** BPSK System Model

where $b_k \in \{0,1\}$ is the binary data and $x_k \in \{\sqrt{E_b}, -\sqrt{E_b}\}$ is the baseband BPSK symbols. The carrier $\emptyset(t)$ is defined as

$$\emptyset(t) = \sqrt{\frac{2}{T_b}} \cos(2\pi f_c t)$$

The channel impulse response $h(t)$ is given by

$$h(t) = A_h e^{j\theta_h} \delta(t)$$

equivalently, h(t) can be written as

$$h(t) = (h_r + jh_i)\delta(t)$$

- The amplitude of the channel impulse response $A_h$ is a random variable drawn from Rayleigh distribution.
- The phase $\theta_h$ is a random variable which is uniformly distributed over $[0, 2\pi]$ interval.
- The real part of the channel impulse response $h_r$ is a Gaussian random variable with zero mean and variance equal to 1/2

- The imaginary part of the channel impulse response $h_i$ is a Gaussian random variable with zero mean and variance equal to 1/2

The Additive White Gaussian Noise (AWGN), $n(t)$ is given by

$$n(t) = n_c(t)cos(w_c t) - n_s(t)\,sin(w_c t)$$

- $n_c(t)$ is a random process, at any specified time instant $n_c(t1)$ is a Gaussian random variable with zero mean and variance equal to $No/2$
- $n_s(t)$ is a random process, at any specified time instant $n_s(t1)$ is a Gaussian random variable with zero mean and variance equal to $No/2$

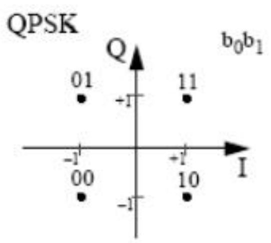
The overall system model can be obtained as

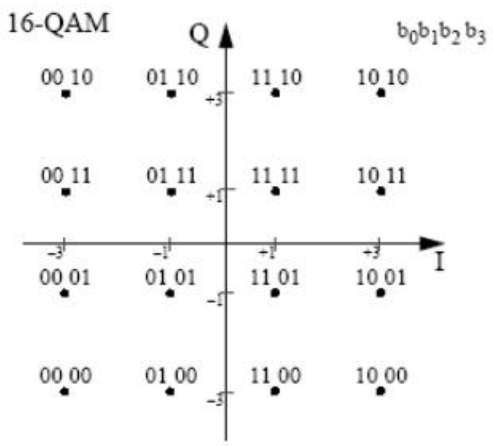
$$y_k = (h_r + jh_i)_k\, x_k \;+\; (n_c + jn_s)_k \;\; k = 0, 1, 2, \ldots$$

Steps of BPSK BER simulation over Rayleigh fading channel is as follows

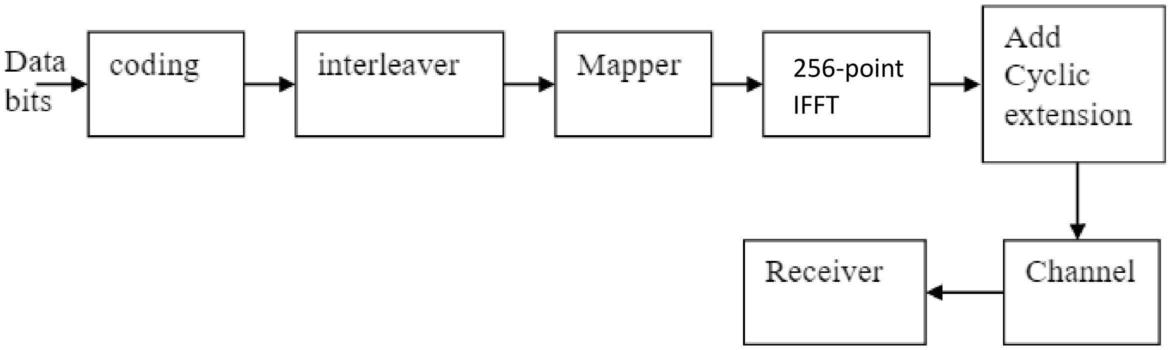
a. Generate Random Bit stream $b_k = [0,1,0,1, \ldots]$
b. Generate BPSK symbols based on the bit stream $x_k = [-\sqrt{E_b}, \sqrt{E_b}, -\sqrt{E_b}, \sqrt{E_b}, \ldots]$
c. Generate the complex channel vector $(h_r + jh_i)$ and complex noise vector $(n_c + jn_s)$ based on the distributions explained above.
d. Compute the received symbol vector $y_k = (h_r + jh_i)_k\, x_k \;+\; (n_c + jn_s)_k \;\; k = 0, 1, 2, \ldots$
e. Compensate for the channel gain at the receiver (assuming the channel is **known** at the receiver), apply correlator and hard decision decoding to estimate the transmitted bit stream $\hat{b}_k$
f. Compute the bit-error rate (BER) for SNR = $E_b/No$
g. Change the noise level then repeat steps a. through f.
h. Plot the BER against SNR.
i. Repeat the above steps using a rate 1/5 repetition code. This is done by transmitting every "1" as five "1's" and every "0" as five "0's".

Repeat the simulation procedures but instead perform QPSK and 16-QAM modulation scheme with the following constellations:



# Problem 3: OFDM system simulation




The above blocks are described as follows:

1. **Coding:**
   Either no coding or rate 1/5 repetition code are used. Note that you have to adjust the number of input bits per OFDM symbol when using repetition code. For example, if you use QPSK, only 51 data bits will be used per symbol, 1 zero is added to the encoded data to have 256 bits at the input of the mapper before the IFFT block.

2. **Interleaver:**
   For QPSK, the size of the interleaver is 32 by 16.
   For 16QAM, the interleaver size is 32 by 32.

3. **Mapper:**
   The mappers used are the same as those in the single carrier system above.

4. **IFFT:**
   Use a size 256 IFFT block. In MATLAB use the command "IFFT"

5. **Channel:**
   Two channel models should be considered:
   a. **Rayleigh flat fading channel:** Same as single carrier system
   b. **Frequency selective Fading channel:** In order to model some type of frequency selective fading channel, assume that every sub-channel is independently faded by a different Rayleigh fading channel. Note that this fading should be modeled in the frequency domain.

6. **Receiver:**
   Design a receiver to receive the signal described above in the two cases of the channel model.

**Requirements:**
Plot the BER against SNR for BPSK, and 16-QAM modulation schemes, for the two channel models mentioned above and for coding and no coding scenarios (4 cases for each modulation scheme).