Communication Theory

Spring-2024

Course Project — Deadline: 5th May, 11:55pm (tentative)

Instructions:

- Clearly state the assumptions (*if any*) made that are not specified in the question.
- Submission Format: "Rollnumber.zip". The zip file should contain 2 folders.
  1st Folder: should contain all MATLAB files.
  Folder name : **Code**
  2nd folder : should contain the Report(pdf format).
  Folder name : **Report**
- Submit a report (pdf format) depicting the generated plots (if any) with answers to questions asked as part of the simulation exercise. State the parameter values used for simulation in the report clearly. Report all observations made and explain why they are so, even though not explicitly mentioned in the question. Marks obtained will depend upon clarity in report writing.
- **Cautions:**
  (a) Zero marks for late submissions.
  (b) Zero marks if plagiarism is detected.
  (c) Submission will not be considered if not submitted in the above-mentioned format.
- For different sections in the project there may be n sub-parts. You must attempt
  (Group number % n)th sub-question where % is the modulus operator.
  For example: If there are 5 sub-parts and your group number is 12, then you must only attempt (12%5) which is the second sub-part of the section.
- **DO NOT** use any direct in-built function to perform the tasks without consent from any of the TA's.

1 Introduction

In this project, you will be required to use everything you have learnt in this course and simulate your own communication model on MATLAB. Figure 1 depicts the block diagram which you will be required to follow. Attached is a link containing the audio file you need to recreate after giving it as input to the model simulation.

2 Procedure

Below is a description of the different blocks you need to implement based on the block diagram given above.

2.1 A/D converter

In this block, you need to convert the .wav file provided to you and convert it into bits as an input to the model. You may use direct MATLAB functions to perform this task. This link may be useful.

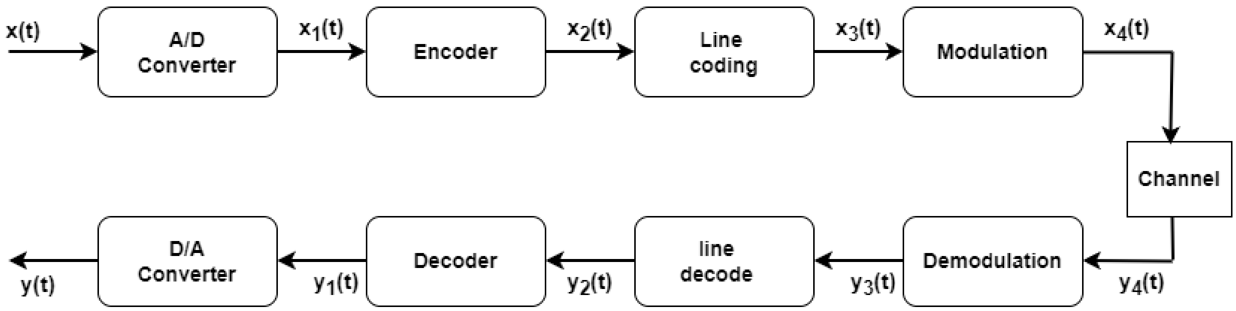


Figure 1: System model

2.2 Encoder

This block is responsible for conversion of the bit stream/sequence into a sequence of symbols a_k. Depending on your team no., you will implement one of the following encoding schemes. Implement the scheme numbered (your team no. % 6).

0. **4-ary amplitude-shift keying (ASK)**
   Here you will map 2 consecutive bits to an amplitude level, as follows,

$$00 \rightarrow 0, 01 \rightarrow 1, 10 \rightarrow 2, 11 \rightarrow 3$$

1. **4-ary frequency-shift keying (FSK)**
   Here two consecutive bits map to a frequency value, as follows,

$$00 \rightarrow f_c, 01 \rightarrow f_c + \Delta f, 10 \rightarrow f_c + 2\Delta f, 11 \rightarrow f_c + 3\Delta f$$

   You need to decide the value of Δf based on the theory you have learnt (and the sampling rate you should have found in section 2.1 :)).

2. **Binary phase-shift keying (BPSK)**
   This is the familiar BPSK coding scheme you learnt ages ago in InfoComm, which looks like this,

$$0 \rightarrow a, 1 \rightarrow -a$$

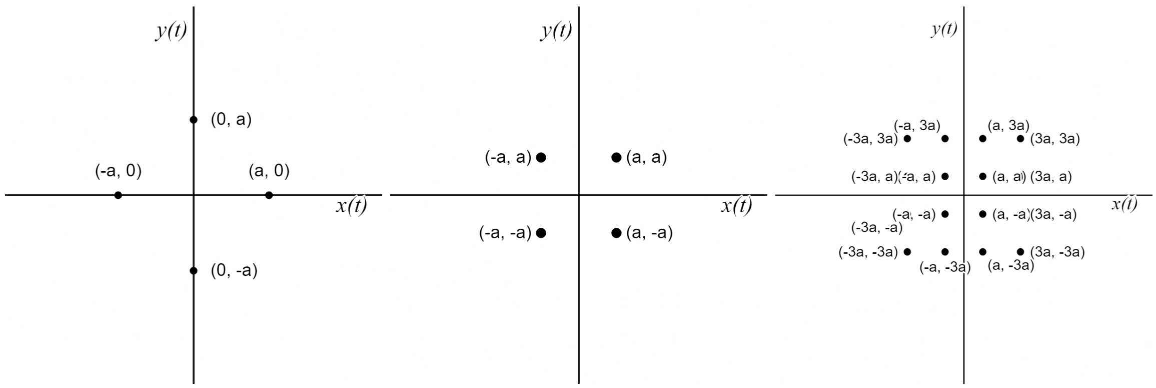
   You can use any value for a.

3. **Quadrature phase-shift keying (QPSK) type 1**
   The constellation for this scheme is as shown in Fig. 2(a).

4. **Quadrature phase-shift keying (QPSK) type 2**
   The constellation for this scheme is as shown in Fig. 2(b).

5. **16-ary quadrature amplitude modulation (16-QAM)**
   This is the APSK modulation scheme whose constellation diagram is shown in Fig. 2(c).

For the scheme you are implementing, you need to include in your report, the SNR (assume AWGN), BER and power efficiency of your scheme.



(a) QPSK type 1 (b) QPSK type 2 (c) 16-QAM

Figure 2: Constellation mappings

2.3 Line coding

In this subsection, you will have to generate the output of the block for the line coding scheme according to

$$\mathbf{x}_3(t) = \sum_k a_k p(t - kT_b),$$

where $p(t)$ is a pulse of duration T_b. Implement the line coding for two different pulse shapes:
1. Rectangular pulse, and
2. Raised cosine pulse.

2.4 Modulation

In this subsection you will have to modulate the output of the line coding block to obtain the signal which can be passed to the channel. The modulation scheme you will use will depend on the scheme used for the encoder block. Following are the modulation schemes for different encoder schemes:

1. For ASK, perform Amplitude modulation
2. For FSK, perform Frequency modulation
3. For BPSK and QPSK, perform Phase modulation
4. For QAM encoding scheme, perform quadrature amplitude modulation.

For a particular modulation scheme you are free to choose different implementations of the scheme as taught in the course. For examples, in amplitude modulation, you may choose to use DSM-SC or SSB depending on the advantages and disadvantages of both schemes. In the report clearly mention why you have chosen this scheme. Also show plots of your signal after modulation in the report. For visualisation purposes, you can use a carrier frequency of 100 Hz just for the plots. For the final communication model, you need to use a carrier frequency of 1MHz.

2.5 Channel and Demodulation

After modulating the signal, you must pass this through the two following channels,

1. Memoryless AWGN channel

$$r(t) = s(t) + n(t)$$

2. AWGN channel with memory

$$r(t) = h(t) * s(t) + n(t)$$

   where, $h(t) = a\delta(t) + (1-a)\delta(t - bT_b)$

$s(t)$ denotes the transmitted signal and $r(t)$ the received signal. Once you have passed the signal through the channel, you need to design the demodulation, line decoder and symbol decoder blocks according to the schemes you have implemented above. Add the plots of the outputs of every block in the report and clearly mention observations made from the plots.

List of outputs expected

- Plot the output of every block: $\mathbf{x}_1(t), \mathbf{x}_2(t), \mathbf{x}_3(t), \mathbf{x}_4(t), \mathbf{y}_1(t), \mathbf{y}_2(t), \mathbf{y}_3(t), \mathbf{y}_4(t)$
- Plot the PSD's of $\mathbf{x}_3(t), \mathbf{x}_4(t), \mathbf{y}_3(t), \mathbf{y}_4(t)$
- Probability of error P_e vs SNR for both the channel realizations mentioned above. Also, provide a comparative analysis.
- Plot the input and output constellation for both the channel realizations and observe the difference.

Note: Clearly mention all the calculations involved to support your results.