Communications and Wireless Networks @CS.NYCU

Lab. 1: path loss and modulation

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Deadline: 2024.04.30 23:59

Agenda

- Overview
- Tasks
- Report
- Submission
- Grading Policy
- Appendix

Overview

In this lab, we are going to write a Matlab program that simulate narrow-band communications over a link of d (meters)

d (input)

Rx

Tx

Rx Gain = 1

Freq = 2.4 GHz
Tx Power = 10 dBm
Tx Gain = 1

Tasks

1. Calculate Rx power
2. Generate channel (h)
3. Generate packets and modulation
4. Simulate sample receiving with noise
5. Decode and demodulate
6. Calculate average noise and SNR
7. Calculate BER, PDR and throughput
8. Plot figures and write the report

Note:

- Don't use any Matlab library(e.g fspl(), awgn(), modulation()) to complete tasks!
  (get no point if you use any Matlab library)
- Add **rng(0)** to fix the random seed

Task 1: P_{rx}

- Given a link distance, derive P_{rx} (in both watt and dB) based on the path loss model
- Use Friss' Free space model
  - Frequency: 2.4 GHz
  - Tx and Rx gains: 1
- Tx power: 10 dBm
  - Remember to convert the power unit

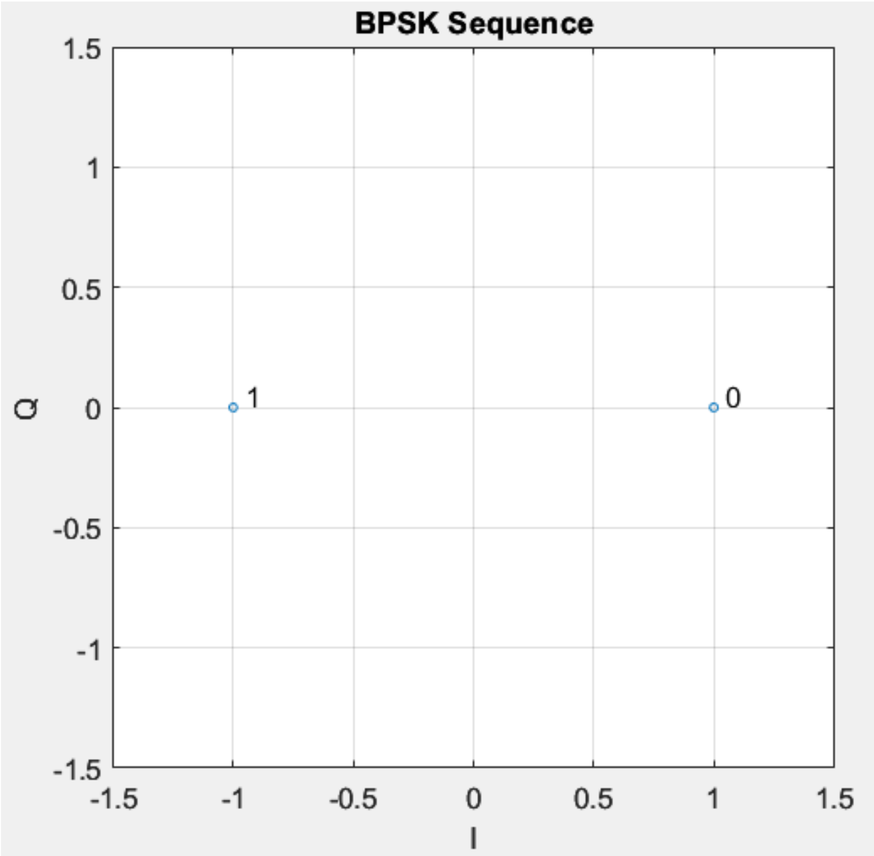
Task 2: Channel Generation

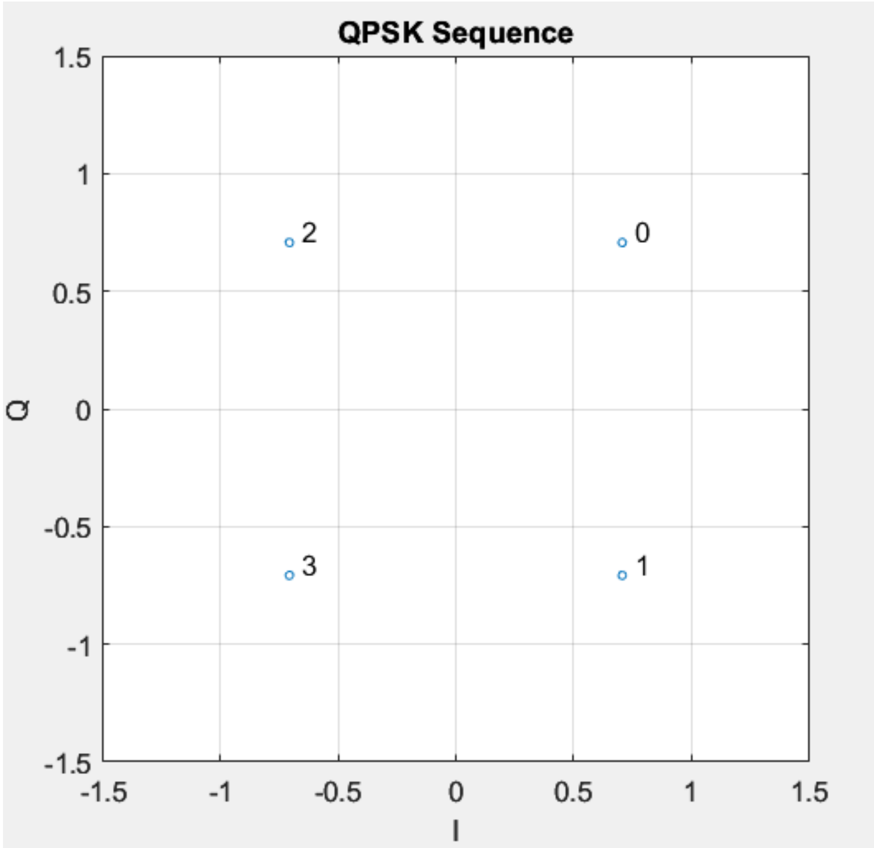
- Generate a random channel $h = a+bi$ following the Gaussian normal distribution
  - $a \sim N(0,1)$
  - $b \sim N(0,1)$
- Use randn() to generate the Gaussian normal sample with zero mean and unit power N(0,1)
- Scale h to the receiving power P_{rx} (in Watt)
- Note: you only need to generage a single random channel for the whole simulation

Task 3: Modulation

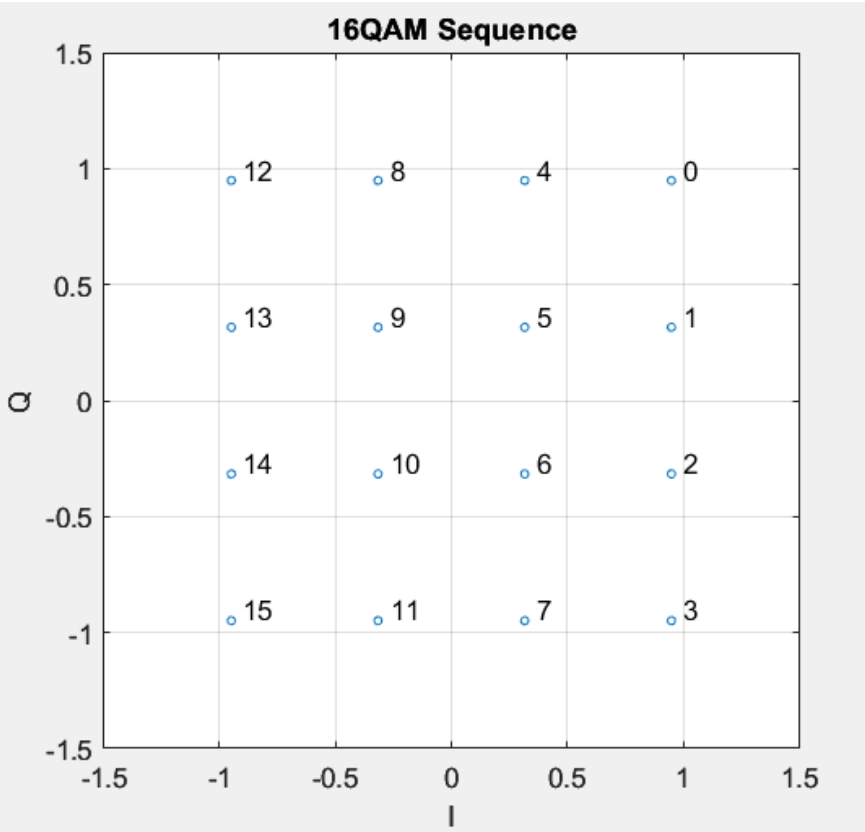
- Generate a message with 300,000 random bits
- Modulate 300,000 bits to N samples
  - BPSK: 300,000 samples
  - QPSK: 150,000 samples
  - 16QAM: 75,000 samples
  - 64QAM: 50,000 samples
- Modulate samples to the complex values according to the mapping tables given in the next slides
  - Make sure the average power should be 1

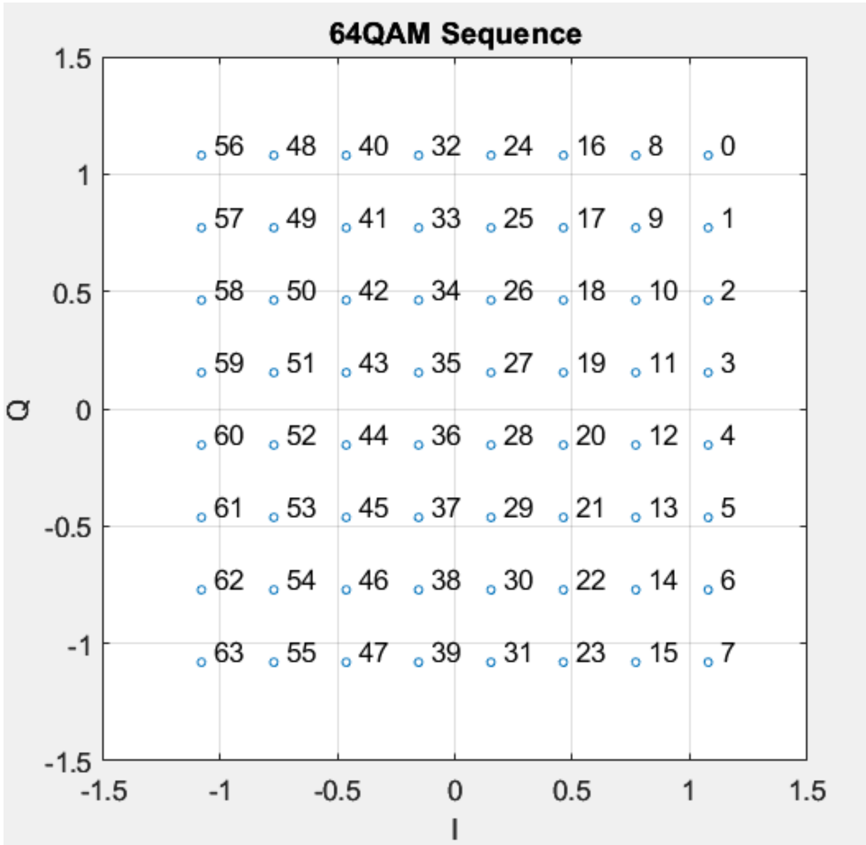
Task 3: Modulation





Task 3: Modulation





Task 4: Transmit over the Air

- Simulate sample receiving with the white Gaussian noise
  - $y_i = hx_i + n_i$
- Generate a vector of N noise samples
  - Noise power: N0 = -90dBm (you may have to convert it to the power in Watt)
  - AWGN (additive white Gaussian noise) model
    - n~N(0, N0)
    - Use randn() in Matlab
  - Note: when you test different modulation schemes, you may generate different numbers of data samples (say K). Remember to use the same noise vector and pick the first K of the N noise samples

Task 5: Decode and Demodulation

- Decode the received samples by zero-forcing
  - $x_i' = y_i/h$
- Demodulate x_i' to the closest constellation point $\widetilde{x}_i$
  - For BPSK and QPSK, use the sign of samples to demodulate the samples
  - For 16QAM and 64QAM, demodulate based on the Euclidean distance

Task 6: Calculate SNR

- Calculate the empirical noise for each sample
  - $\tilde{n}_i = x_i' - x_i$
- Calculate the average empirical noise power (in both watt and dBm)
  - Hint: Compare the empirical noise power with the added theoretical noise power (i.e., -90 dBm)
- Calculate the empirical SNR and SNR_{dB}
  - Hint: Compare the empirical SNR with the theoretical SNR (i.e., theoretical SNR derived from the path loss model P_{rx} – N0)

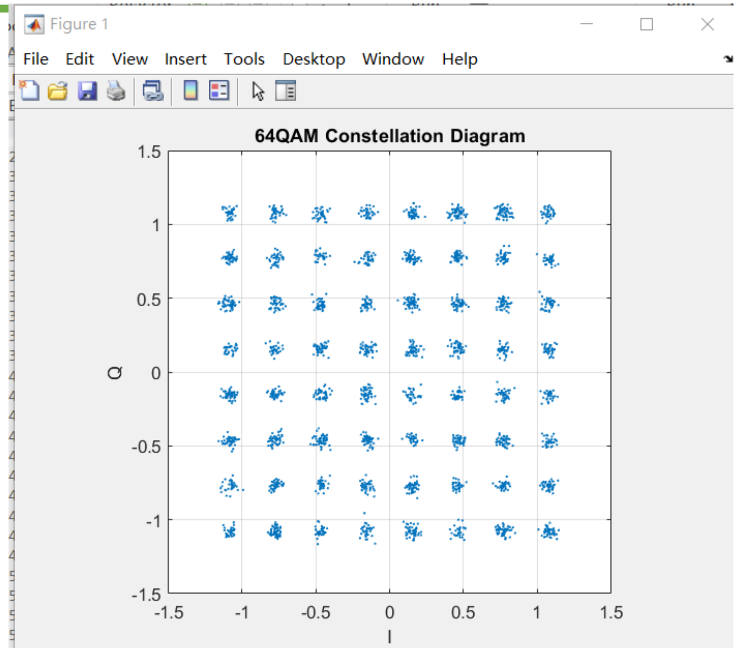
Task 7: Calculate Throughput

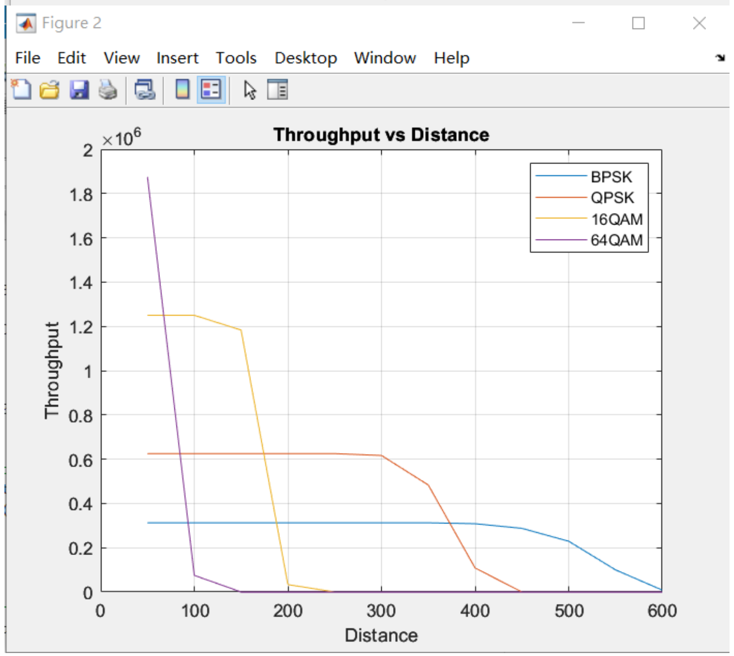
- Assume that the sample duration is 3.2 μs and the message is encapsulated into packets of 500 bytes
- Calculate the empirical bit-error rate (BER)
- Calculate both the theoretical PDR $(1\text{-BER})^{bit\_num}$ and empirical PDR (number of packets are successfully delivered)
- Calculate both the theoretical and empirical throughput (in bit/s)
- Output the empirical SNR_{dB}, BER and throughput of each modulation scheme
- Output the optimal modulation scheme for a given link distance d

Task 8: Plot Figures

- Constellation Diagram
  - BPSK with 40m
  - QPSK with 20m
  - 16QAM with 10m
  - 64QAM with 5m

- Throughput vs. distance
  - d: 50-600m (interval 50m)





Report

A report in PDF format, contains:

- Output your results for d=[50:50:600]
  - P_{rx} (in watt and dBm) derived from the path loss model
  - Empirical and theoretical average noise power (in watt and dBm), SNR and SNR_{dB}
  - Empirical BER of each modulation scheme
  - Empirical and theoretical throughput of each modulation scheme
  - The optimal modulation scheme for link distance d
  - Figures specified in page 14

Report

A report in PDF format, contains:

- Answer the following question in short:
  - Assume there exists a theoretical modulation table given in SNR_BER.mat(also in Appendix 1)
    - What is the theoretical optimal modulation scheme for link distance *d* and packet size *l*? (You can write a Matlab code to output the answer)
    - Compare your empirical rate selection with the optimal selection and describe your observation
  - What have you learned from this lab?
  - What difficulty have you met in this lab?
- Notice: You should write your report in English

Submission

- Submit the following files to the assignment in Teams 112-2 CWN
  - Matlab code (StudentID.m)
  - Report (in pdf) (StudentID.pdf)
- Deadline: 2024.04.30 23:59

Notice: No need to submit to E3

Grading Policy

- Grade
  - Code correctness - 40%
  - Report - 60%
- Late Policy
  - (Your score) * 0.8^D, where D is the number of days over due
- Cheating Policy
  - Academic integrity: Homework must be your own – cheaters share the score
  - Both the cheaters and the students who aided the cheater equally share the score

Appendix

- SNR/BER Modulation Table

MOD/SNR	1	2	3	4	5	6	7	8	9	10	
BPSK	0.099960	0.082042	0.065987	0.051512	0.039193	0.028793	0.020165	0.013462	0.008542	0.005048	
QPSK	0.143398	0.119090	0.096090	0.074595	0.055572	0.039138	0.026083	0.016028	0.009015	0.004500	
16QAM	0.324322	0.308590	0.292187	0.275385	0.258042	0.240303	0.223118	0.207107	0.191428	0.176778	
64QAM	0.374972	0.364988	0.354340	0.343302	0.331572	0.319182	0.305930	0.291118	0.275283	0.258457	
MOD/SNR	11	12	13	14	15	16	17	18	19	20	
BPSK	0.002778	0.001357	0.000588	0.000193	0.000058	0.000022	0.000002	0.000000	0.000000	0.000000	
QPSK	0.001987	0.000735	0.000233	0.000070	0.000010	0.000000	0.000000	0.000000	0.000000	0.000000	
16QAM	0.162830	0.149923	0.137320	0.124772	0.112590	0.100592	0.088662	0.076910	0.065573	0.054567	
64QAM	0.240443	0.221528	0.201453	0.181692	0.162157	0.143013	0.125063	0.108050	0.092923	0.078910	
MOD/SNR	21	22	23	24	25	26	27	28	29	30	31
BPSK	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
QPSK	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
16QAM	0.044390	0.035165	0.027260	0.020240	0.014243	0.009622	0.006152	0.003617	0.001960	0.000950	0.000000
64QAM	0.066238	0.054960	0.045082	0.035713	0.027602	0.020487	0.014467	0.009773	0.006115	0.003352	0.000000