MSc Module: Communications Systems Modelling
Lab Session 0 – Introduction to MATLAB Programming & BER Simulations

0.1 Basic MATLAB Commands

0.1.1 >> 3+4
0.1.2 >> x=[1 2 3 4 5]
0.1.3 >> y=[6;7;8;9;10]
0.1.4 >> y'
0.1.5 >> whos, who
0.1.6 >> clear ans, clear all
0.1.7 >> save filename.mat
0.1.8 >> u=0:8
0.1.9 >> u=0:2:8
0.1.10 >> u(1:3), u(1:2:4)
0.1.11 >> A=[1 2 3;4 5 6;7 8 9]
0.1.12 >> A(2,2), A(:,1), A(2,:), A(1:2,2:3), A'
0.1.13 >> A*A, A.*A, A.^2
0.1.14 >> Some scalar functions: sin, cos, tan, asin, acos, atan, exp, log, abs, sqrt, rem, round, floor, ceil
0.1.15 >> Some vector functions: max, min, length, sort, sum, prod, median, mean, std
0.1.16 >> Some matrix functions: eye, zeros, ones, diag, triu, tril, rand
0.1.17 >> More matrx functions: size, det, inv, rank, rref, eig, poly, norm, cond, lu, qr, chol, svd
0.1.18 >> plot(x,y), xlabel, ylabel, title, legend
0.1.19 >> function [a,b]=fname(x,y)
0.1.20 >> for i=1:10,

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  I=i+2;
end
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0.1.21 >> Relational operators: <, >, <=, >=, ==, ~=, &, |, ~
0.1.22 >> if, elseif, else, end
0.1.23 >> help, clc, ls, % … and more (please refer to the MATLAB primer as well)

0.2 Simple Simulations

0.2.1 Write a MATLAB code to generate a random sequence of N BPSK symbols $\{\pm 1\}$.
- What is the average energy of the symbol sequence?
- How can you be sure that the generated sequence has the right statistical properties?

0.2.2 Write a MATLAB code to generate a random sequence of N QPSK symbols $\{\pm 1 \pm j\}$.
- What is the average energy of the symbol sequence?
- If we like to normalise the average energy to unity, what changes should we make?

0.2.3 Write a MATLAB code to generate a random sequence of N 16-QAM symbols $\{(\pm 1 \text{ or } \pm 3) + (\pm j \text{ or } \pm 3j)\}$.
- What is the average energy of the symbol sequence?
- If we like to normalise the average energy to unity, what changes should we make?

0.2.4 Generate a large number of complex zero-mean Gaussian random variables with variance of σ^2 and observe the probability density functions (pdfs) of the amplitude and its phase.

0.2.5 Produce a sequence of the received signals which is the summation of 16-QAM symbols and complex Gaussian noise. Plot the signals on a complex plane and vary the SNR to see how the results are affected.

0.3 BER Simulation of a QPSK Communication System with Gaussian Noise

0.3.1 Write a MATLAB code that generates a sequence of N QPSK symbols with normalised energy (*x*)

0.3.2 Write a MATLAB code that generates a sequence of N Gaussian noise samples (mean 0, variance σ^2) (*n*)

0.3.3 Write a MATLAB code that generates a sequence of noisy received signal samples ($y = x + n$)

0.3.4 Write a MATLAB code that counts the number of detection errors (hint: think about how to perform detection at the decoder with the received noisy signal samples)

0.3.5 Write a MATLAB code that evaluates the BER of the system (note: in order to have an accurate BER estimate, it is important to have sufficient number of simulations; N$\geq$10/BER)

0.3.6 Defining the signal-to-noise ratio (SNR) as SNR=$1/\sigma^2$, conduct the BER simulations for SNR from 0 to 20 dB and plot the results using "semilogy". Note that different SNR values are achieved by varying σ.

0.3.7 Repeat the simulations for 16-QAM. Make sure to normalise the average symbol energy. The outcome should be a plot of the BER results against the average SNR.

0.3.8 Repeat the simulations for 64-QAM. Make sure to normalise the average symbol energy.

0.4 BER Simulation of a QPSK Communication System in Flat Fading Channels

0.4.1 Write a MATLAB code that generates a sequence of N QPSK symbols with normalised energy (*s*)

0.4.2 Write a MATLAB code that generates a sequence of N Gaussian noise samples (mean 0, variance σ^2) (*n*)

0.4.3 Write a MATLAB code that generates the Rayleigh flat fading channel coefficients (*h*)

0.4.4 Write a MATLAB code that generates a sequence of the received signal samples ($y(k) = h(k)s(k) + n(k)$)

0.4.5 Write a MATLAB code that counts the number of detection errors if coherent detection is used. Note that detection should be done by removing the perturbation of the channels:

$$\tilde{s}(k) = \begin{cases} +1, & \text{if } \mathrm{Re}\left\{\dfrac{y(k)}{h(k)}\right\} > 0, \\ -1, & \text{if } \mathrm{Re}\left\{\dfrac{y(k)}{h(k)}\right\} \leq 0, \end{cases}$$

0.4.6 Write a MATLAB code that evaluates the BER of the system. Refer to the lecture notes if needed. Important to note: the BER results should be averaged over a large number of independent channels to be meaningful; otherwise, the BER results will depend on the specific samples of the channels.

0.4.7 Plot the BER results on a graph for various SNR. Note: use "semilogy" again.

0.4.8 Repeat the simulations for 16-QAM and 64-QAM