# Advanced Communication Systems (2024 - 25)

# Assignment 1

## General Instructions

Write a report on your work, which should include the following parts:

* Methodology – explain how you set up the simulation and chose the parameters for each part. There is no need to repeat the information in this document.
* Results – give clearly labelled graphs of results for each part, and give sufficient details to allow someone to reproduce them.
* Validation – compare your results with standard theoretical or published results, where possible.
* Conclusions - briefly summarise your findings, explain their significance, and make specific recommendations for improved communication link designs.

Submit your report as a pdf file of no more than 6 pages, including all the graphs. A suggested breakdown is three pages maximum of text and three pages of graphs of results. Remember the graphs and annotations must be readable. Also, submit your MATLAB code as .m or .mlx files, with appropriate explanatory comments embedded in them. As part of the assessment process the code may be run by the assessor to verify the results given in the report.

## Marking Scheme

The work will be marked out of 100. Part 1 will carry a weight of 30%, Part 2 30% and Part 3 30% of the overall mark. Presentation accounts 10%. Detailed marking schemes can be found in the Task section.

The whole assignment is also subject to the University’s English Language Proficiency marking criteria that states that an assignment will receive a fail if the standard of English is poor, defined as:

“Poor standard of written English, making it difficult to understand the points being made. Weaknesses of writing are so frequent or serious that they impede communication.”

It is expected that all work will be carried out individually and detected cases of plagiarism will be treated according to the University’s code of practice.

## Use of Generative AI

The use of Generative AI to complete or enhance a student’s assignment is NOT allowed. This is in line with the University’s policy on Generative AI. The University’s full policy can be found here <https://www.birmingham.ac.uk/libraries/education-excellence/gai>

In particular, note that “enhance” is defined as “Rewriting or editing of text with the purpose of improving the Student’s research arguments or contributing new arguments or rewriting computer code is not acceptable, whether undertaken by a person, by generative AI or by any other means, and may be deemed to be plagiarism.”

## Assignment Task

The future 6G mobile communication system is likely to see further densification of the radio units in a cell-free and distributed multi-antenna (D-MIMO) systems. It will also utilise new spectrum in the Frequency Range 3 (FR3) between 7 and 24 GHz. In this assignment, you will simulate one radio link between such a radio unit (RU) and a user equipment (UE) in a D-MIMO grid covering a 100 m by 100 m area. The link distance is nominally 25 m. There are 16 RU in this grid. Imagine this grid covers an urban square with a high density of users or in a factory with wirelessly connected machines, robots, vehicles and human operators.

The link operates at 15 GHz with a usable bandwidth up to 400 MHz. The RU-UE data rate is designed to reach 500 Mbps, using 64-QAM and a number of other deployment features.

The assignment will build upon work you have done in the first five weeks of the module on modulation, noise and propagation. You are required to simulate in MATLAB a communication system using some of the models to which you were introduced during the module, starting from a simple channel model with AWGN and then building up in complexity by adding further details and effects to determine how they affect the Bit Error Ratio (BER) and constellation diagrams.

# Part 1

Simulate the 500 Mbps RU-UE link operating with a 15 GHz carrier frequency in Matlab using the script assignment1.m as a starting point. The link uses a 64-QAM modulation scheme and includes AWGN noise. Note that we are just simulating the complex envelope of the communication signal and not the RF signal at the carrier frequency.

Implement pulse shape filtering by adding root raised cosine filters at the output of the transmitter and the input of the receiver. You may wish to use the objects *comm.RaisedCosineTransmitFilter and comm.RaisedCosineReceiveFilter* in the MatlabCommunication Systems toolbox. Choose a suitable value for the roll-off factor. Explain and justify the choice of the parameters for the root raised cosine filters. Investigate and explain the impact of the roll-off factor on the performance of the link.

Perform the simulation for different values of SNR, choosing a suitable range of values (guided by the theoretical graph given in the lectures), and use your results to produce a graph of the Bit Error Ratio vs Eb/N0. Compare this with the theoretical curve shown in the lectures. Hint: Carefully consider a large enough number of bits or symbols that are required to numerically approximate the theoretical BER curve. Show some example constellations in your report.

Marking criteria (Part1):

* Implementation – filtering, BER as a function of SNR [15]
* Explain and justify the choice of the parameters for the root raised cosine filters. [5]
* Investigate and explain the impact of the roll-off factor on the performance of the link. [5]
* Constellation diagrams. [5]

# Part 2

Now consider some impairment effects on your communication link. For each of the following cases, plot the resulting constellation diagram, explain what the impairment (phase offset and phase noise, respectively) is, briefly describe the problem created and propose a technical solution.

1. A phase offset between the transmitter and receiver local oscillators. You can implement this by introducing a time-constant phase offset to the received signal. Hint: use object *comm.PhaseFrequencyOffset* or multiply the received signal by an appropriate complex exponential.
2. Phase noise in your receiver local oscillator. This can be simulated by adding phase noise to your received signal using the *comm.PhaseNoise* object. Assume a phase noise level of ‑50 dBc/Hz at a frequency offset of 20 Hz from the carrier frequency.

Marking criteria (Part2):

* Implementation – phase offset and phase noise [10]
* Constellation diagram. [6]
* Explain what the impairment (phase offset and phase noise, respectively) is. [6]
* Briefly describe the problem created by phase offset and phase noise, and propose a technical solution. [8]

# Part 3

Consider the urban square deployment scenario. Between the RU and UE, there is usually a line-of-sight (LOS) link. However, slow and fast fading must be considered. Building on what you studied, apply appropriate channel models to your signal, between the transmit filter and the AWGN. Using what you have learnt about fading channels, choose suitable sets of the channel parameters (e.g. the number of multiple paths and their relative amplitudes and delays, and the maximum Doppler shift) to create one example of each of the two cases:

* Use the two-ray channel model, choose and justify the parameters for the deployment scenario and implement it in Matlab. You can do this by adding an attenuated time-delayed version of your transmitted signal to the received line-of-sight signal. Assume a surface reflection coefficient of 0.1 and the difference between the two paths is 2 m.
* Select the appropriate fast fading model for the deployment scenario and implement it in Matlab.

State any reasonable assumptions in your report. Plot the resulting BER curve and constellation diagram. Explain what features you would include in your transmitter and/or receiver to overcome the fast fading effect.

Marking criteria (Part3):

* Implementation – two-ray interference [10]
* Implementation - fast fading model [5]
* State any reasonable assumptions in your report. [5]
* Plot the resulting BER curve and constellation diagram. [5]
* Explain what features you would include in your transmitter and/or receiver to overcome the fast fading effect. [5]

Presentation of the Matlab codes and the report. [10]