EGH443 - Advanced Telecommunications Assignment 2 (30%)

Released: 22nd April 2020

Due: Sunday 24th May 2020

Completed in Groups of 3 students or individually

Congratulations! Your company recently won a bid to design and implement a multi-carrier wireless communication system to provide wireless broadband services to a regional city in Queensland. Mobile service providers have overlooked this community due to economic considerations. Deployment of standard communications systems are costly, and the Queensland government is looking for a cheaper alternative.

In this task you will perform following tasks to design and test a viable wireless communication system for the above application.

Data collected from an extensive measurement campaign commissioned by Queensland Government can be used to place base station antennas at strategic locations to maximize reliability and coverage. The channel measurement campaign has found that the wireless channel in the intended coverage area shows multi-path characteristics with number of delayed paths with significant delays and a set of measured data is available to estimate the path loss exponent.

You can extract the path loss data and the measured channel delay profile parameters by following the instructions in Part 1. Each group/student will have a unique set of data based on your student IDs.

Preliminary Instructions

Download all files to be used in Assignment 2 from blackboard and place them into one working directory. Please also unzip the contents of assignment2.zip into this directory.

There are 2 files contained within assignment2.zip:

1. initialise.m - used to generate the data used in this assignment.
2. A2GenData.p - called by initialise.m

Workspace Preparation

Open initialise.m with MATLAB and read its instructions. Proceed to insert your group number and the student IDs into the script and generate your data for this assignment. The channel delay profile data will be stored in 'channel.mat'.

The initialise.m script only needs to be executed ONCE.

Part 1 – Estimate Path Loss Exponent of the Channel

Large scale fading can be modeled as a combination of the path loss and log normal shadowing. The path loss L_{dB} in dB as a function of distance d is calculated by

$$L_{dB} = L_{0,dB} + 10n\log_{10}\left(\frac{d}{d_0}\right) + X_\sigma$$

where $L_{0,dB}$ is the path loss in dB obtained at the reference distance of d_0 away from the transmitter, n the path loss exponent and X_σ the shadowing component. The shadowing component is Normally distributed when the path loss is specified in dB, and has zero mean with a standard deviation of σ also specified in dB.

In this part you will be estimating the value of n and σ from data in following two variables.

- d: This vector corresponds to the distance between transmitter and receiver at which a measurement was taken. The units are in meters.
- LdBShadow: This matrix stores the data captured in a measurement campaign. Each row of the matrix corresponds to a new measurement trial. The units are in dB.

1.1 Present the measured path loss data at different distances in a scatter plot. Describe the reasons for variations observed in the measurement at a given distance.

1.2 For each of the distances inside d, calculate the average path loss and plot in a separate figure.

1.3 Use the MATLAB built in function **fitlm** to find a linear model for the given data and Estimate the path loss exponent.

1.4 Assuming transmitter and receiver antenna gains are 15dB and 1dB respectively, receiver sensitivity of -88 dBm, and fade margin of 25 dB estimate the minimum transmitted power required if the receiver is 4 km away from the transmitter.

1.5 For each of the distance inside d, calculate the standard deviation and find an estimate for the standard deviation of X_σ

Part 2 – Design an OFDM System

You are asked to design a fixed wireless access (FWA) system to provide wireless broadband services to regional Australia. Your system should be capable of offering a 100 Mb/sec download speed using a 40 MHz band centered around 3.6 GHz spectrum. Remember you need to optimise the bandwidth usage and choose the smallest possible modulation scheme to offer good bit-error-rate performance at low transmit power.

2.1 Load the channel channel.mat file and extract the variables pvec and tvec, where pvec and tvec are channel time delay vector in nanoseconds and the delayed relative power vector of the channel in dB respectively. Plot and label the multipath impulse response of the channel.

2.2 Estimate the rms delay and the coherence bandwidth of the channel.

2.3 If the data requirement of the system is 150 Mbps, design your OFDM system using above information. You need to decide following parameters of your system.

- N - Number of sub-carriers.
- T - OFDM Symbol duration
- T_g - Guard interval
- m - Modulation index (smallest possible.)

Justify your selections.

NOTE: The guard interval $T_g > 10 \times \sigma_\tau$ and the Sub-carrier bandwidth $\Delta(f) \leq \frac{B_c}{10}$, where B_c is the coherence bandwidth of the channel.

2.4 Estimate the maximum data rate of your system if the maximum allowable modulation index is 10 (1024-QAM). Compare this data rate with that of an equivalent single carrier system and comment of the observations.

2.5 Write a MATLAB code to simulate the performance of the OFDM system in AWGN channel. Simulate and plot the bit error rate performance within the bit-error rate (BER) range from 0.5 to 10^{-5} and compare with the theoretical bit-error rate performance (Do not use built-in MATLAB functions to implement the OFDM system).

You can use built-in MATLAB functions in this step. Some of the useful MATLAB functions would be, fft, ifft, qammod, awgn and biterr.

2.6 Comment on the observed bit-error-rate performances and describe in detail **two** methods that can be used by a practical communication system to improve the bit error rate at the receiver.

Part 3 – Flat fading Channel

You are able to meet the required data-rate at AWGN channel. Now, you need to simulate the performance of above OFDM system in a Rayleigh fading channel with the impulse response given by pvec and tvec.

$$h(t) = h\,\delta(t)$$

where h is a Gaussian random variable with zero mean and σ_h variance. For the following simulation assume $\sigma_h = 1$.

Simply adding the two Gaussian Random variables and taking the square root (envelope) gives a single tap Rayleigh distributed process. The phase of such random variable follows uniform distribution. Consider two Gaussian random variables with zero mean and same variance X and Y. Let's define a complex Gaussian random variable as $X + i \times Y$. The envelope follows Rayleigh distribution and the phase will be uniformly distributed. The probability density function (Rayleigh distribution) of the above-mentioned amplitude response is given by

$$f_A(a) = \frac{a}{\sigma^2} \exp\left(-\frac{a^2}{2\sigma^2}\right)$$

3.1 Create two vectors with 10000 samples of a complex Gaussian random variable, **h** with variance 1 using randn command and find the envelope of and plot its normalised histogram. Compare the normalised histogram against the theoretical Rayleigh distribution.

3.2 If X_n, $(n = 1, 2, \ldots N)$ is the vector of modulated symbols. The ODFM signal can be generated by,

$$x_k = \text{ifft}(X_n), \quad k = 1, 2, \ldots N$$

Assuming the fading channel is stationery during the OFDM symbol duration, we can find the frequency response of the channel using,

$$H_n = \text{fft}(h) \quad n = 1, \ldots N$$

The **FFT** output at the receiver can be expressed as

$$Y_n = H_n X_n + n_n$$

Therefore, the received signal can be recovered using a single tap equalisation,

$$\tilde{X}_n = \frac{Y_n}{H_n} = X_n + \frac{n_n}{H_n} = X_n + \tilde{n}_n$$

Now, $\tilde{X}_n$ can be demodulated to extract the transmitted data. You can assume that full channel information is available at the receiver for the following simulation. In practice, channel needs to be estimated using pilot symbols.

Write a MATLAB code to simulate the performance of OFDM system in flat Rayleigh fading channel within the E_b/N_0 range from 0 dB to 30 dB. Simulate and plot the bit error rate performance and compare with the theoretical bit-error rate performance and the bit-error rate performance in AWGN channel.

3.3 Compare bit error rate performance in AWGN channel and flat fading channel and Comment on the observations.

Reflection (Mandatory)

Each member of the group should write a reflection and appended to the end of your report. Include a short discussion of about 100 words that addresses problems encountered, any lessons learned and things that you would have done differently. This section is mandatory, and the assignment is regarded as incomplete if absent. If you had any group concerns throughout the duration of your assignment, please address them here.

Academic Integrity Declaration (Mandatory)

The provided Academic Integrity Declaration must be completed and submitted along with the assignment. Assignments with incomplete or missing declarations are not marked.

Report and Code Presentation (Specific-Question and/or Overall Deductions)

This assignment includes elements of written and coding assessment. One assignment report and one set of code should be submitted for each group or individual (depending on how the assignment has been completed). Marks are based on how easily and effectively ideas are articulated to the reader. The CRA has the outlines to the marking standards.

The Report Component

An outstanding report demonstrates knowledge and understanding of the subject area. It will communicate ideas clearly and logically with a combination of visual, mathematical and code assets. Correct information not articulated clearly will also attract deductions.

Present the report so that it can be understood without reference to the assignment brief. Any figures or code referenced within the code should be no more than one page turn away.

Document flow and coherency is to be prioritized. Reports that are difficult to navigate are marked poorly in these criteria. This means avoid the use of "see appendix" and "refer to .m file".

It is important that all code and justification for each part is included in your report submission. Your report is being marked; your code is included for justification.

Mathematical working that shows the logical procedure or justification of how you arrived at your solutions are required. This working need not be typed but it is expected to be legible and able be followed in a coherent manner.

Include a title page that states the unit name, unit code, assignment number, your name and student number. **Do not include a table of contents, list of figures, nor a list of tables.**

Convert the report to the PDF file format before submission. This ensures document typesetting is preserved across different computers running different operating systems.

The Code Component

Working code is expected to be submitted alongside your report to Blackboard. The code needs to be executable (in .m) and without run-time error. No error correction will be made to make your code "run". If an error is encountered at execution, your assignment cannot be marked. Coding for this assignment should remain within one file (unless otherwise explicitly instructed). Only include additional .m files if necessary. Using a separate file for each sub section constitutes poor code management.

Code should be fully commented to describe intent. Quality comments encapsulate your understanding of the topic.

You may use the code provided in the weekly tutorials to check your solutions. However, you are expected to generate your own code for your assignment.

Submission Protocol

Submission deadline is on Sunday 24 May 2020. This will be a hard deadline and late submission penalties will apply. As per QUT policy, late assignments receive 0 marks.

Assignments are to be submitted in soft copy through QUT Blackboard as a single .zip file that includes the following

- A completed and signed academic integrity declaration in PDF format.
- The report in PDF format (Handwritten report are not acceptable.)
- initialise.m with your student ID/s of you/your team.
- *channel.mat* file generated during workspace preparation.
- MATLAB script/s you have developed because of explicit assignment instructions.

The submission link is accessible through: EGH443 20se1 → Assessment → Assignment 2 → Assignment 2: Submission. You may submit as many times as you like before the deadline. New submissions overwrite old submissions. Only the latest submission is recorded and marked. All documents can be reviewed after submission and thus it is your responsibility to verify that the uploaded documents are not corrupt. Corrupt files are treated as incomplete assignments.

Be aware that the electronic time stamp is placed only **after** all files have uploaded. Do not risk the late penalty and submit early.