EGB342 Assignment 1 (15%)

Released: Friday, 9th August 6:00pm (Week 3)
Due: Sunday 1st September, 11:59pm (Week 6)
Group Assignment - (Group of 3 students)

Hearing about your previous signal analysis expertise, Fraser Island tourism manager Natalie has commissioned you to do some preliminary analysis for a possible radio station to be constructed. This radio station is to be used for emergency communication on the island. It is a public radio station, so sudden weather events or natural disaster information will be broadcast on this station. It has been decided to utilise the FM transmission protocol. Fraser Island is quite small, so distance is not a huge concern, thus FM was chosen over AM. This assignment will focus on the analogue aspects of FM.

***Reminder* Read the entire document before attempting the questions**

Preparation

Remember that these tasks are being conducted so Natalie can assess the viability of the station. This means that the overall goal is not achieved if she does not understand the information you provide. Fortunately, Natalie's tourism degree had a minor in engineering, which introduced her to basic scientific concepts and logical reasoning. Your task is to bridge the gap between her knowledge and your findings using clear, well reasoned explanations and appropriate graphical and mathematical assets. Also assume she does not want to flip between documents, so ensure all relevant contextual information from the brief is in the **final report.**

Part 1: FM Theory

This section will test your theoretical understanding of Frequency Modulation. This will prepare you for Part 2 and Part 3 of the assignment. Part 1 can be handwritten and scanned, or typed. Add any MATLAB code you use to *A1Training.m*. Assign values to the listed variables where possible. Set Part 1 listed variables that you don't use to zero.

(a) To test a proposed radio link, a carrier with frequency **fc1** is frequency modulated by a single tone with a frequency **fm** using a frequency sensitivity factor of $k_f = 60000$. The frequency and the peak magnitude of the carrier is 450 MHz and 10V respectively and the frequency and the peak magnitude of the message signal is 15 kHz and 1V respectively.

(b) Find an expression for the modulated signal and compute the maximum frequency deviation, **Df1**, and the modulation index, **beta1**,

(c) Determine how many side-bands should be selected to contain 98% of the modulated signal power. You can use the MATLAB built-in **besselj** function to calculate the Bessel coefficients.

(d) Plot the corresponding magnitude spectrum.

(e) Estimate the bandwidth of the modulated signal using a spectral plot and compare that with the theoretical bandwidth given by Carson's rule.

(f) If the channel is only being used for the voice communications with a 4 KHz message bandwidth and a 25 KHz radio bandwidth on a 450 MHz carrier, estimate the maximum frequency sensitivity factor allowed.

(g) With the help of block diagrams describe the operations of a stereo transmitter and a receiver of FM radio. *Create your own block diagram/s.*

(h) Describe 'Capture effect' in the context of an FM receiver.

(i) If you are asked to use double side-band full carrier AM modulation for the above transmission, calculate the following,

- Modulation index
- Efficiency of modulation
- Bandwidth required.
- Compare this bandwidth with the bandwidth obtained in part (e) and comment on the observations.

Part 2: FM Training

This section will prepare you for the final implementation by simulating the process in a familiar environment. Adherence to the function and variable names that are given is essential.

(a) Download the "Assignment1.zip" files and unzip all the content into a single working directory.

(b) Open the file *GenerateAssignment1Data.m* and carefully read the instructions supplied in the file. Enter **first 7 digits** of the student numbers in the specified variables and run the script. This script only needs to be executed once. Begin working from *A1Training.m* after *A1Data.mat* has been generated.

(c) The signal that you will be using for testing the FM system is given in the variable **msg**. This testing signal is identical to a monitoring signal that will be transmitted over the FM system. Generate the time vector corresponding to this signal and store it in the variable **t2**. Sampling frequency is given in the variable **fs**. Take care in constructing this correctly. Using this time vector, plot the signal in the time domain. *Identify any important features of the signal.*

(d) Estimate the bandwidth of the given message using the spectrum plot and store it in the variable **BW_MSG**. Describe how you estimated the bandwidth.

(e) Testing the FM system requires that a suitable carrier frequency be chosen. The nature of the transmission channel dictates the choice of this frequency.

The channel has been saved into your current working directory in the file *channel.p*. This channel behaves as a linear time invariant (LTI) system. It takes one input **msg_tx** and produces one output **msg_rx**. Think of the output as being a distorted version (channel induced distortions) of the input signal.
The syntax of using the channel is:

[msg_rx] = channel(msg_tx);

Determine the frequency response of the channel using the impulse response and identify suitable frequency band to transmit your message signal. Estimate the bandwidth of the selected frequency band.

Determine a suitable carrier frequency for this channel and store this value in variable **fc2** as a value in Hz. Explain your process and fully justify your answer. Use suitable mathematical developments, code, and graphical assets to aid the justification. The response should be no longer than two pages.

(f) Estimate the maximum frequency sensitivity factor and the corresponding modulation index **beta2** to transmit the given message withing the selected band.

(g) Calculate theoretical bandwidth of the FM signal and peak frequency deviation of the modulation, **Df2**. Store this value in **BW_FM**. Present these values in your report and and state any assumptions made.

(h) Create a MATLAB function **fm_mod** to contain your frequency modulation function. The function header is to conform to the following syntax:

function [msg_tx] = fm_mod(msg, fc2, fs, Df2);

Where **msg_tx** is the modulated signal, **msg** is the signal to be modulated, **fc2** is the carrier frequency (in Hz), **fs** is the sampling frequency (in Hz), and **Df2** is the peak frequency deviation.

(i) Write the body of the frequency modulation function. Do not use the inbuilt MATLAB integration function. Employ the MATLAB **cumsum** function instead.
Remember to include the full function in your report.

(j) You are now at a stage to test your system. Take the baseband signal **msg** and modulate this signal with the **fm_mod** function. Store the modulated signal in the variable **msg_tx**.

(k) Plot the modulated signal in the time and frequency domains. Compare these plots with that of the baseband signal. Examine the differences between the signals, and explain these differences in relation to theory. Comment on the accuracy of your bandwidth calculation.

(l) Plot and verify that your signal is within the selected frequency band. Comment on any out of band radiation observed and discuss measures you can take to remove out-of-band radiation.

(m) Transmit the modulated signal **msg_tx** through the channel using provided function *transmit.p*. Store the result in variable **msg_rx**.

(n) Describe the demodulation process of FM signal and show how you can implement FM demodulation in MATLAB.

(o) Demodulate the signal using the **provided function** and store the result in **msg_rc**:

[msg_rc] = fm_demod(msg_rx, fc2, fs, Df2);

Note that this demodulation function also decodes an emergency message contained within the signal.

(p) You have now finished testing the system. If the transmission has been performed successfully the monitoring string should consist of a message string concatenated with student numbers of the group members and **FRAS-342x** appended to the end.

What was the decoded message?

Ensure the following variables are in the MATLAB work-space after script execution.

Part 1	**Part 2**
fc1 - carrier frequency	**msg** - message
c1 - carrier	**fs** - sample rate
m1 - message	**Df2** - Peak frequency deviation
kf1 - frequency sensitivity	**t2** - time vector
y1 - modulated signal (time)	**BW_FM** - theoretical bandwidth
Y1- modulated signal (freq)	**BW_MSG** - Message bandwidth
beta1-Modulation index	**fc2** - carrier frequency
Df1 - Peak frequency deviation	**msg_tx** - modulated signal
-	**msg_rx** - modulated signal after channel
-	**msg_rc** - recovered message
-	**beta2** - modulation index

Part 3: Radio-frequency Spectrum Measurements

With your FM knowledge from Parts 1 and 2 of the assignment, examine and explore the radio-frequency spectrum around you in preparation for your trip to the island. A chart illustrating how the radio-frequency spectrum is allocated among services in Australia can be found in the link below. For this task you need to borrow a RTL-SDR USB dongle form the technical support services counter at S-block level 9. Each group should borrow only one hardware package.

http://www.acma.gov.au/webwr/radcomm/frequency_planning/spectrum_plan/arsp-wc.pdf

Setting up Hardware and Software

Set up your hardware and software using the following steps.

Step 1 Download and install the RTL SDR Radio Support package into your MATLAB installation. Support package hardware setup can be found at the following link.

`http://au.mathworks.com/help/supportpkg/rtlsdrradio/ug/support-package-hardware-setup.html`

Step 2 Once the installation is complete, connect your RTL-SDR USB dongle and run the following command in MATLAB to confirm the successful installation of hardware and software.

sdrinfo

(a) Write a MATLAB function titled **listen_fm** to listen to a selected FM radio station using RTL-SDR.

(b) Use the ***spectrum_analyser.m*** to scan the spectrum. The syntax of the ***spectrum_sweep.p*** function used in the spectrum_analyser.m script is as follows.

spectrum_sweep(start_freq,stop_freq,rtlsdr_fs, number_samples, location)

- **start_freq** - Starting frequency (Lower frequency of the observation window)
- **stop_frequency** - Stop frequency (Higher frequency of the observation window)
- **rtlsdr_fs** - RLT-SDR sampling rate, allowed range is 225-300 kHz and 900-3200 kHz.
- **number_samples** - Number of samples per frame ($L = 2^n$, where $n < 18$)

(c) Several different spectral bands exist, and are used for different purposes. These include,

1. FM analog radio transmission
2. Digital Audio Broadcasting (DAB)
3. Digital Video Broadcasting (DVB)
4. Mobile Frequencies
5. Queensland Government Wireless Network (GWN)

For each of the listed ranges, scan and plot the frequency spectrum. Also state characteristics of these transmission and the owners of these frequencies.

(d) Discuss the effect of the number of samples per frame, **L**, on the above spectral measurements.

(e) Identify several common radio stations in your current area. Label this on a spectrum plot.

(f) From the information gathered in the previous parts, make an informed decision for a suitable carrier frequency for Fraser Island emergency communication system. Be sure to list all the factors that impacted your decision.

(g) Discuss the advantages and disadvantages of using Digital emergency communications.

Reflection (Mandatory)

A reflection is to be written and appended to the end of your report. Include a short discussion (150 to 200 words) that addresses problems encountered, and things that you would have done differently. Identify what concepts this assignment has reinforced, and areas where you can improve. This section is mandatory and the assignment is regarded as incomplete if absent.

Academic Integrity Declaration and Group Dynamics - Individual (Mandatory)

Each group member must *individually* complete the 'Academic Integrity Declaration and Group Dynamics' online form using the provided link on Blackboard. **Individual marks will be withheld if this is not completed, or if the declaration is not agreed to.** In the group dynamics portion, allocate the percentage contribution of each group member. If you wish, you may add additional text and request the teaching team review member contribution. If you experience issues with group members before the due date, please contact the teaching team via email. If your issues are in hindsight, please give details here.

Interview (Mandatory if requested)

Interviews will take place (at the discretion of the teaching team) to assess the conceptual understanding. This will be a casual discussion. These interviews are compulsory and grades are withheld until they are completed. Marks may be deducted for poor demonstration of content/assignment knowledge. These interviews will only be for selected groups, and you will be notified if you need to take part in an interview.

Presentation Standards

This assignment includes elements of written and coding assessment. You are expected to work as a group. Each group is expected to generate and submit one assignment report and one set of MATLAB code. Marks are based on how easily and effectively ideas are articulated to the reader.

The teaching team has put together some things to consider -

The Report Component

An outstanding report demonstrates knowledge and understanding of the subject area. It communicates ideas clearly and logically with a combination of visual, mathematical and code assets. It demonstrates insight about the underlying concepts and their implications within telecommunications and signal analysis. Verbose responses, or correct information not articulated clearly, will attract deductions.

Remember that you are writing to inform.

Mathematical working shows a logical procedure (or justification) for the final solutions i.e. All non-trivial steps are included. It can be typed or handwritten but must be legible and easily followed.
Code snippets used in-text should only contain relevant lines of code and should rarely have more than five lines in a snippet.

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. Avoid the use of "see appendix" and "refer to `.m` file". Document flow and coherency is to be prioritised. Reports that are difficult to navigate are marked poorly in this criteria.

Write the report assuming that the reader only knows concepts from 1st year engineering and does not have access to your `.m` file/s.

Include a title page that states the unit name, unit code, assignment number, your name(s) and student number(s). **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

The submitted code needs to be executable (in MATLAB R2018a or later) and without run-time error. If an error is encountered at execution, your assignment will only be marked until the error. No error correction will be made to make your code 'run'. Coding for this assignment should remain within one (provided) file (unless otherwise explicitly instructed). Only include a separate `.m` file if absolutely necessary.
Code should be fully commented to describe *intent*. Comments should contain enough information to understand the process without referring to the report. 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. Submitting supplied `.p` code as your own work constitutes academic misconduct and will be considered a run-time error. **

Acknowledgment

spectrum_sweep.p was generated using a spectrum sweep code of Desktop SDR (`http://www.desktopsdr.com/`).

Submission Checklist

Submission deadline is on the **1st September, 2019, 11:59 pm**. This will be a hard deadline and late submission penalties will apply. As per QUT policy, late assignments receive 0 marks.

- ☐ The report, in PDF format, submitted to Turnitin via the Blackboard link
- ☐ A `.zip` file, submitted directly to QUT Blackboard via the provided link, that contains -
  - `A1Training.m` with student IDs of your team
  - Functions that are written as a result of explicit assignment instruction
  - Any other MATLAB scripts you have developed
- ☐ Submissions have been re-downloaded from submission portals and run as-is to confirm successful upload.
- ☐ Online Academic Integrity declaration (Individual).

Submission FAQ

⇒ You do not need to assign your submission with a special name. Blackboard assigns unique IDs to all submissions. The submission links are accessible through: **EGB342_19se2 → Assessment → Assessment Item No. 1: Problem Solving Task → Assignment 1 Submission Links**.

⇒ 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. Upload in-progress versions so there is something to mark if your final submission is late.

⇒ 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. Blackboard may experience high traffic or your connection may fail unexpectedly. Begin your final upload at least an hour before the deadline.

Hardship

If you experience a hardship which affects your ability to complete, or contribute to, this assignment, please contact the teaching team as soon as it occurs.
QUT also offers counselling services if required.

Criteria	Standards						
	7+	7	6	5	4	3	2/1
CR1 - 50% weighting **Theoretical understanding** **Key Milestones** **- Use of FM-related equations** **- Mathematical working** **- Sound reasoning for technical choices** **- Modulation methods/ Modulator architecture** **- FM placed in a real-world context**	Demonstrates understanding of the mathematical concepts underpinning this assignment beyond the expected '7' level. Explanations and justifications are unambiguous, accurate and logical. Graphical and mathematical tools are used masterfully to convey knowledge of all topics. Uses appropriate terminology. Has no conceptual errors, but one minor technical/numerical error may exist. Discusses all required concepts and shows evidence of further research.	Demonstrates in-depth understanding of the fundamental concepts in this assignment. Explanations and justifications are generally clear, accurate and logical. Graphical and mathematical tools are used fittingly to convey knowledge of all topics. Uses appropriate terminology. Has no conceptual errors, but one minor technical/numerical error may exist. Discusses all required concepts.	Demonstrates strong understanding of the fundamental concepts in this assignment. Explanations and justifications are generally accurate and logical. Graphical and mathematical tools are used satisfactorily to convey knowledge of all topics. Uses appropriate terminology. Has no conceptual errors, but minor technical/numerical errors exist. Discusses all required concepts.	Demonstrates sound understanding of the fundamental concepts in this assignment. Explanations and justifications are generally accurate and logical. Graphical and mathematical tools are used satisfactorily to convey knowledge of most topics. Uses appropriate key terminology. One minor conceptual error and no more than two technical/numerical errors may exist. Discusses all key concepts.	Demonstrates rudimentary understanding of the fundamental concepts in this assignment. Explanations and justifications are generally accurate and logical but are sometimes unclear. Graphical and mathematical tools are used adequately to convey knowledge of most topics. Uses appropriate key terminology. Only minor conceptual, technical or numerical errors exist. Discusses most key concepts.	Conceptual understanding is not demonstrated explicitly OR Major conceptual error OR Discussion does not demonstrate understanding of the expected '4' level.	Incorrect interpretation/s of underlying concepts i.e. Multiple major conceptual errors. Does not recognise basic errors when discussing generated diagrams.
CR3 - 20% weighting **Effective written communication** **Key Milestones** **- Informative** **- Easy to read** **- Clearly explained core ideas** **- Reflection demonstrates intended learning outcomes**	Professional format, insightful, core technical ideas are clearly, accurately and succinctly conveyed. The report is **very** easy to read, and has been written to inform. **Only** relevant code included in snippets. Figures demonstrate intended point excellently. Referencing is present, and has been done correctly (IEEE). Reflection shows all learning outcomes were reached.	Professional format, core technical ideas are clearly and accurately conveyed. The report is easy to read, and has been written to inform. **Mostly** relevant code included in snippets. Figures demonstrate intended point very well. Reflection shows all learning outcomes were reached.	Professional format, technical ideas are clearly conveyed, one minor inaccuracy. The report is informative and easy to read. **Mostly** relevant code included in snippets. Figures demonstrate intended point well. Reflection shows most learning outcomes were reached.	Report format is adequate but missing some coherence in its structure. The report is difficult to read in one or two sections. Consistently irrelevant code included in snippets. Figures demonstrate intended point satisfactorily. Reflection shows some learning outcomes were reached.	Report format is missing several critical explanations. The report is difficult to read in several parts. Large amounts of irrelevant code included. Figures demonstrate intended points adequately. Little evidence of reflective thinking.	Report formatting was attempted. Contains little, or vague, discussion and lacks cohesion. Largely a code and figure dump. No evidence of reflective thinking.	The report has little or no structure. No evidence of reflective thinking.
CR2 - 30% weighting **Application using Coding**	**Key Milestones – For a 7 in this criteria, all milestones must be satisfactorily reached; For a 6, most must be satisfactorily reached, and so on.** • Correct individual-question outputs as per solution-script options Code *appears* to give correct outputs if widely-varying solutions are possible • Code is optimised (i.e. makes use of vectorisation where appropriate) • Comments are effectively used to describe the code • No runtime errors • Uses functions that are within the scope of the assignment • Code achieves desired output/s on completion					Large sections of code incomplete OR Multiple runtime errors	
For moderation of overall marks: At the discretion of the teaching team, your group may be selected to attend an interview if the teaching team require clarification about how the group arrived at their solutions, or how individuals contributed to the overall solution. If selected, you will be notified and given details of the location and time of the interview.							
Oral interview	Demonstrated knowledge is consistent with submitted report and code. No moderation of marks.				Demonstrates knowledge noticeably below the standard of the submitted report and code. Individual marks may be moderated down up to 20%.	Demonstrates knowledge significantly below the standard of the submitted report and code OR Does not attend interview. Individual marks may be moderated down up to 100%.	