EGB242 Assignment 1 - Part B (20%)

Individual Assignment

Released: Friday 3rd September, 11:59PM (Week 6)
Final Assignment Due: Friday 24th September, 11:59PM (Week 9)

Message from MARS-242 Mission Control

The Spaceship MARS-242 is getting closer to Mars and the astronauts are getting used to the spaceship environment. However, the signs of boredom are starting to show in how the astronauts are feeling, and sometimes in how they attend to their assigned tasks. This has always been a possibility due to the extended length of the journey, as no space mission with humans on board a spaceship has taken this long before. The mission planners thought to deal with such a situation, if it arose. One option is for the astronauts to be able to either listen to some of their favourite pieces of music, or play a piece of music and broadcast during their travel to Mars.

There are a number of signal analysis problems that require your expertise and assistance to make this happen. In this assignment you will be asked to apply the signal analysis techniques you have learnt in this unit to contribute to solving this technical challenge.

Preparatory Instructions

Follow these steps for preparation:

i **Read through the entire document before attempting the tasks.**

ii Open GenerateDataAssignment1B.m in your MATLAB working directory. Carefully read all of the comments and follow all the instructions in the file. This file generates the data you will need for this assignment.

iii Write down the functions displayed in the command window when you run the GenerateDataAssignment1B.m file.

iv Section B1 is to be completed on MATLAB Grader. MATLAB Grader will provide immediate feedback on the questions answered. **Remember to try your solutions in your own MATLAB environment, and submit only when you have checked the correctness of your solutions.**

v Section B2 will be submitted as a report. You will be writing MATLAB code in mission.m to perform the required tasks and submit your results in a report format.

vi As a guide, a report with all sections complete should be between **8 and 10 pages**, including figures and code.

vii **Ensure that all work (including process description, code used and plots) are included within the report. An example report showing how this should be presented is available on Blackboard.**

Section B1 (Approximate periodic noise)

This section should be submitted **in MATLAB Grader** *with hand-working included as an appendix in your report.*

The mission directors at the BASA Headquarters have designed a training exercise to be a primer on Fourier transforms. Complete these exercises during your appointment as an intern signal processing engineer at BASA. This section will have you perform the Fourier Transform by hand, then validate your results with MATLAB.

This section of the assignment is to be completed through MATLAB Grader, available through the link below:

MATLAB Grader for Assignment 1B

Section B2 (Mars Mission: Preparation)

The Frequency-shift property allows us to shift signals from their original band of frequencies to another (usually much higher) band. It states that the multiplication of a signal with bandwidth B by a cosine (or sine) function of frequency f_c shifts the existing spectra to occupy new locations at $f_c \pm B$ and $-f_c \pm B$. Individual data streams can be added together (multiplexed) into a single stream without interference provided that each stream is shifted to its independent non-overlapping frequency bands, and can also be extracted later.
BASA Engineers have utilised this powerful property and now several pieces of music have been selected, combined and transmitted to the spaceship, where they need to be separated to be delivered to each of the astronauts.

An example of a sound wave in the time domain and its corresponding frequency domain magnitude spectrum is shown in Figure 1. Notice that most of the energy in the signal is concentrated between 0 and 6 kHz. We can say that this particular signal is band limited and that it has a bandwidth of B = 6 kHz.

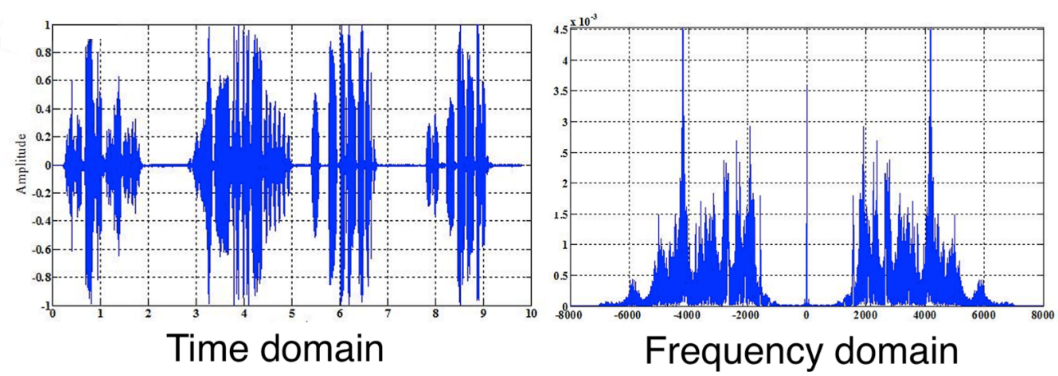

Figure 1: A sound wave shown in both time and frequency domains

Section B2 (Mars Mission: Combining Signals)

The hardware module responsible for removing the frequency shift and extracting music and text signals has malfunctioned. Your task is to perform the necessary signal processing on the raw data to manually extract the signals.

Open the mission.m file. All code for this part of the assignment should be written into this file. Read all comments and note all key variables that need to be explicitly declared.

B2.1 The two variables loaded into the workspace are **muxSignal** and **fs**. The raw data stream of the music and text signals are stored in **muxSignal** while **fs** contains the sampling frequency. Determine the sampling period, store it inside the variable **Ts** and then use this to construct a time domain vector, **t**, that corresponds to **muxSignal**. Plot **muxSignal** against this time vector. (CR1a, CR2b)

B2.2 Compute the Fourier transform of **muxSignal** and store this in **MUXF**. Also construct a frequency vector, **k**, suitable for plotting the magnitude spectrum of **MUXF**. Plot the magnitude spectrum of **MUXF**. (CR1a, CR2a)

B2.3 The peaks in the magnitude spectrum give the precise locations of the frequency shifts. Identify the location of the peaks in the positive frequencies (you may use an inbuilt MATLAB function) and store them inside a row vector called **freqshifting** in ascending order. **freqshifting** values should be whole numbers, round to the nearest integer if necessary. (CR2a, CR2b)

B2.4 Find the magnitude and phase of these peaks. Store the results in row vectors **MagSpec** and **PhaseSpec** respectively. The values in these vectors need to correspond to their respective frequencies in **freqshifting**. Create a new figure and overlay the locations and magnitudes of the frequency shifts using red circles on the magnitude spectrum of **MUXF**. You will have between 4 and 6 circles. (CR1a, CR2b)

B2.5 Develop a frequency shifting module called FDMDemux.m for use in your code following the syntax:

[**xdm**] = FDMDemux(**muxSignal**, **t**, **freqshifting**, **MagSpec**, **PhaseSpec**)

The function must be able to handle an input signal with any number of streams. Use this to remove frequency shifts for all five music signals. Input variables **muxSignal**, **t**, **MagSpec**, **freqshifting**, and **PhaseSpec** should be inserted as row vectors. Upon successful application of the module, each row of the **xdm** matrix will contain the data for one signal with frequency shift removed. Remember to include your completed function code, and explanation in the assignment report. (CR2a, CR2b)

B2.6 Compute the Fourier transform for each data stream in **xdm** (row by row). Store the result in the matrix **XDM**. Plot the magnitude spectrum for each data stream. Explain why the streams are unsuitable to listen to or decode in their current state. (CR1a, CR2a, CR2b)

B2.7 Examine the plots in B2.6 to determine a bandwidth value which can be used for *each* of the streams of the spectrum to be retained and stored in **B**. B is a vector of values that apply to each shifted component individually. State and discuss why you have selected this. Once the bandwidth has been determined, construct an ideal low pass filter (i.e. Rectangular function) that will isolate each shifted component individually. Pass each shifted signal through the ideal low pass filter and then remove any DC offset from the signal (centre the time domain waveform around 0). (CR1a, CR1b, CR2a)

B2.8 Play the audio streams using the inbuilt MATLAB function **sound()** and decode the data streams using the supplied function A1BTextdecode.p. Do not use the function **soundsc()**. Which of the streams are audio, and which are text? The function takes the coded time domain signal and sample rate as inputs. The usage for the function is as follows,

decodedtext = A1BTextdecode(**codedinput**, **samplerate**)

If correct, you should receive between 2 and 4 pieces of text, and 2 pieces of music. Identify any audible traits of each piece of music (ie instruments, style, lyrics, etc) and include the decoded text in your report. (CR1a, CR1b)

MATLAB variables that should be included in your workspace for section B2 (mission.m),

Ts - Sampling period
t - time vector
MUXF - Fourier transform of muxSignal
k - Frequency vector
freqshifting - frequency shifts (vector)
MagSpec - magnitude of peaks (vector)
PhaseSpec - phases of peaks (vector)
xdm - output of FDMDemux (matrix)
XDM - Fourier transform of xdm (matrix)
B - Bandwidth
filteredoutput - Filtered Output Signal
decodedtext - The Decoded Text Output

Section B3 (Reflection)

A two paragraph reflection is to be written and appended at the end of your report. In the first paragraph summarise how you demonstrated your understanding of the concepts used in this assignment. The second paragraph should be a discussion/professional reflection that covers any lessons learned from doing this assignment, and things that you would have done differently. Each paragraph should not exceed 250 words. Marks for this are included as part of the criteria available on appended CRA sheet.

Academic Integrity

If academic misconduct is discovered, the suspected student/s will be given an opportunity to explain the similarities to the teaching team. If no response is received within 1 business day of first contact, the matter will be escalated to the faculty, which may affect the release date of final marks for the unit. **Please take this seriously.** Do not share your code or report with other students, or use other student's code or reports.

Submission

This assignment includes elements of writing and coding. You are required to submit:

1. Solutions to the problems posed in MATLAB Grader *(submitted in MATLAB Grader with hand-working included as an appendix within your report)*;
2. One assignment report *(submitted through Turnitin on Blackboard)*;
3. One set of MATLAB code *(submitted on Blackboard)*; and
4. One Data1B.mat file *(submitted on Blackboard)*.

The attached Criteria Reference Assessment (CRA) sheet has the outlines of the marking standards of this assignment.

The Report (Criteria: CR3)

An outstanding report demonstrates clear knowledge and understanding of the subject through a combination of visual, mathematical and coding elements. Correct information that is not articulated clearly will attract deductions. **Remember that you are writing to inform.**

- Present the report so it can be understood without reference to the assignment brief.
- You should only include code that is relevant to the question. Avoid the use of "refer to .m file".
- Include a full copy of your code attached in the appendix of the report clearly readable.
- Include your MATLAB Grader hand-working as an appendix of your report.
- Include a title page that states the unit name, unit code, your name and student ID number.
- **Do not include a table of contents, list of figures, nor a list of tables.**

The MATLAB Code

Working MATLAB code is expected to be submitted, alongside your report to Blackboard. The code needs to be executable (in *.m) and **without** run-time errors. No error correction will be made to make your code "run."

Interview

You may be selected and contacted to attend an interview if the teaching team requires clarification about how you arrived at your solutions. Interviews 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 understanding of content or assignment knowledge. Consult the CRA sheet for the guidelines of what is expected.

Table of Fourier Transform Pairs

	$x(t) = \mathcal{F}^{-1}\{X(f)\} = \int_{-\infty}^{\infty} X(f)e^{j2\pi ft}\,df$		$X(f) = \mathcal{F}\{x(t)\} = \int_{-\infty}^{\infty} x(t)e^{-j2\pi ft}\,dt$	
transform	$x(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$X(f)$	
complex conjugation	$x^*(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$X^*(-f)$	
time shifting	$x(t-t_0)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$e^{-j2\pi ft_0}X(f)$	
	$e^{j2\pi f_0 t}x(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$X(f-f_0)$	frequency shifting
time scaling	$x(at)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\frac{1}{\lvert a\rvert}X\left(\frac{f}{a}\right)$	
reversal	$x(-t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$X(-f)$	
duality (symmetry)	$X(-t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$x(f)$	
linearity	$ax_1(t)+bx_2(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$aX(f)+bX(f)$	
multiplication	$x_1(t)x_2(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$X_1(f)*X_2(f) = \int_{-\infty}^{\infty} X_1(\zeta)X_2(f-\zeta)\,d\zeta$	
convolution	$x_1(t)*x_2(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$X_1(f)X_2(f)$	
	$= \int_{-\infty}^{\infty} x_1(\lambda)x_2(t-\lambda)\,d\lambda$			
delta function	$\delta(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	1	
shifted delta function	$\delta(t-t_0)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$e^{-j2\pi ft_0}$	exponential decay
unit doublet	$\dot{\delta}(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$j2\pi f$	
unit step	$u(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\frac{1}{2}\delta(f)+\frac{1}{j2\pi f}$	
signum	$sgn(t) = \begin{cases} 1 & t>0 \\ -1 & t<0 \end{cases}$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\frac{1}{j\pi f}$	
exponential decay	$e^{-at}u(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\frac{1}{a+j2\pi f}$	
two-sided exp. decay	$e^{-a\lvert t\rvert}$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\frac{2a}{a^2+4\pi^2 f^2}$	
gaussian	$e^{-a^2t^2}$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\frac{\sqrt{\pi}}{a}e^{-\frac{4\pi^2 f^2}{a^2}}$	
sine	$\sin(2\pi f_0 t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\frac{1}{j2}\left[\delta(f-f_0)-\delta(f+f_0)\right]$	
cosine	$\cos(2\pi f_0 t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\frac{1}{2}\left[\delta(f-f_0)+\delta(f+f_0)\right]$	
sinc	$F\mathrm{sinc}(Ft)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\Pi_F(f) = \mathrm{rect}\left(\frac{f}{F}\right)$	
gate function	$\Pi_T(t) = \mathrm{rect}\left(\frac{t}{T}\right)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$T\mathrm{sinc}(Tf) = \frac{Tsin(\pi Tf)}{\pi Tf}$	
triangular function	$\Lambda_T(t) = \begin{cases} \left(1-\frac{\lvert t\rvert}{T}\right) & \lvert t\rvert<T \\ 0 & \text{else} \end{cases}$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$T\mathrm{sinc}^2(Tf)$	
	$tx(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\left(\frac{j}{2\pi}\right)\frac{d}{df}X(f)$	frequency differentiation
	$t^n x(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\left(\frac{j}{2\pi}\right)^n \frac{d^n}{df^n}X(f)$	freq. n-th differentiation
time differentiation	$\frac{d}{dt}x(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$j2\pi fX(f)$	
time n-th differentiation	$\frac{d^n}{dt^n}x(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$(j2\pi f)^n X(f)$	
integration	$\int_{-\infty}^{t} x(t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\frac{1}{j2\pi f}X(f)+\frac{1}{2}X(0)\delta(f)$	
modulation	$x(t)\cos(2\pi f_0 t)$	$\overset{\mathcal{F}}{\longleftrightarrow}$	$\frac{1}{2}\left[X(f-f_0)+X(f+f_0)\right]$	

Criteria and Standards for Grading

Criteria	Standards						
CR1a – Theory:	MATLAB Grader Task 40% Weighting						
CR2a - Design	MATLAB Grader tasks are awarded grades based on the successful completion of the problems included in "Assignment – 1B: Signal Analysis with Fourier Transform."						
	CR1. Conceptual understanding 25% Weighting						
	7+	**7**	**6**	**5**	**4**	**3**	**2/1**
CR1a – Theory: **Derive** Fourier transforms (FTs) of signals by hand calculations and **verify** using computationally evaluated expressions.	Demonstrates exceptional understanding of the mathematical concepts behind Fourier transform (FT) and its properties, through the use of graphical and mathematical methods that are clear, accurate and logical.	Demonstrates accurate understanding of the mathematical concepts behind Fourier transform (FT) and its properties, through the use of graphical and mathematical methods that are clear, accurate and logical.	Demonstrates mostly correct understanding of the Fourier transform (FT) mathematical concepts, using graphical and mathematical methods used are clear and logical.	Demonstrates sound understanding of the FT mathematical concepts using clear and accurate graphical and mathematical methods.	Demonstrates adequate understanding of the FT theoretical concepts, using logical graphical and mathematical methods.	Shows minimal or incoherent understanding of theoretical concepts. Explanations or calculations have major errors.	No evidence of understanding of theoretical concepts. Few or no calculations.
CR1b - **Justify** the use of magnitude and phase spectra and **explain** the relationship between frequency- and time-domain representations.	• Thoroughly justifies both quantitatively and qualitatively, the selection of parameters, methods, and techniques. • Shows evidence of further research with appropriate references.	• Thoroughly justifies the selection of parameters, methods, and techniques.	• Justifies the selection of parameters, methods, and techniques.	• Justifies the selection of parameters, methods, and techniques with one error or has omitted one necessary justification.	• Justifies the selection of parameters, methods, and techniques with a few errors or has omitted a couple necessary justifications.	• Mostly fails to correctly justify the selection of parameters, methods, and techniques.	• Fails to correctly justify any selection of parameters, methods, and techniques.
	CR2. Application using MATLAB Coding 25% Weighting						
	7+	**7**	**6**	**5**	**4**	**3**	**2/1**
CR2a - Design effective code to represent signals and spectra using FT and **generate** time and frequency vectors.	• Well-commented MATLAB code with all appropriate simplifications and optimisations performed. • MATLAB functions have been developed to optimise code for repeated processes.	• Well-commented MATLAB code with most of the appropriate simplifications. • Most optimisations are performed.	• MATLAB code is commented throughout. • Many simplifications and optimisations are performed.	• MATLAB ode is commented. • Some simplifications and/or optimisations are performed.	• MATLAB code has some structured approach but is difficult to follow. • Only occasional simplifications performed.	• MATLAB code is unstructured. • Code is difficult to follow and exhibits major flaws.	• Little attempt is made to write MATLAB code.
CR2b – **Evaluate** and **interpret** signal spectra using FFT and supplied functions.	• Correctly calculates all required variables with no errors.	• Correctly calculates all required variables with only a couple minor errors.	• Correctly calculates all required variables with a few minor errors.	• Calculates all required variables with several minor errors or one major error.	• Calculates required variables with many minor errors or a couple of major errors. There must be no run time errors in the code.	• Attempts to calculate required variables with more than a couple major errors or run time error.	• No attempts to calculate required variables.

	CR3. Effective written communication 10% Weighting						
	7+	**7**	**6**	**5**	**4**	**3**	**2/1**
Assignment solution is presented in a Report format considering: **CR3a - Structure, CR3b –Integration, CR3c – Figures, graphs and tables CR3d – Reflections and Contextualisation.**	• Professional report format, that is easy to read and core technical ideas are clearly and accurately conveyed. All processes and solution steps are clearly outlined. • Code is seamlessly integrated into the report and are used effectively to convey ideas in the report. Code snippets are selectively chosen to succinctly demonstrate all necessary key technical ideas. • Figures are effectively used throughout the report to demonstrate results and facilitate explanations. Figures are labelled and plots are appropriately scaled and visible. • Solution is contextualised to the MARS242 mission, and includes **reflections** conveying accurate technical knowledge and insights.	• Professional report format, that is easy to read and core technical ideas are clearly and accurately conveyed. Almost all appropriate processes and solution steps are clearly outlined. • Code is integrated into the report and are used to convey the ideas in the report. Selected code snippets demonstrate all key technical ideas. • Figures are effectively used throughout the report to demonstrate results and facilitate explanations. Figures are labelled and plots are appropriately scaled and visible. • Solution is contextualised to the MARS242 mission, and includes **reflections** conveying accurate technical knowledge.	• Professional report format, that is easy to read and core technical ideas are conveyed. Most of the appropriate processes and solution steps are clearly outlined. • Code is integrated into the report and are used to convey ideas in the report. Selected code snippets demonstrate most key technical ideas. • Figures are used throughout the report to demonstrate results and facilitate explanations. Figures are labelled and plots are appropriately scaled and visible. • Solution is contextualised and includes **reflections**. conveying accurate technical knowledge.	• Report is mostly easy to read and most core technical ideas are conveyed. Some key explanations of processes and solution steps are missing. • Code is integrated into the report and are used to convey ideas in the report. Code snippets are used. • Figures are used to demonstrate results and facilitate explanations. Most figures are labelled and plots are appropriately scaled and visible. • Solution is contextualised and includes **reflections**.	• Report is missing some key components of a report. Report is difficult to read in some parts and some core technical ideas are conveyed. Many key explanations of processes and solution steps are missing. • Code is not integrated into the report or is not used to connect with the ideas discussed in the report. • Figures are included but do not demonstrate results or facilitate explanations. Some important figures are missing. • Solution contains some contextualisation and **reflections**.	• Report is missing multiple key components of a report. Report is difficult to read. A significant number of key explanations of processes and solution steps are missing. • Code is not integrated and is mostly a code and figure dump. • Multiple key figures are missing and little effort has been made to link the figures with the report. • Attempts to contextualise the solution but with no **reflections**.	• Report has little to no structure. Large portions of the report are missing/not attempted. • Code is incorrect or missing from the report. • Figures are almost entirely missing from the report. • No contextualisation or **reflections**.

For moderation of overall marks: At the discretion of the teaching team, you may be selected to attend an interview if the teaching team require clarification about how you arrived at your solutions, or to demonstrate conceptual understanding. If selected, you will be notified and given details of the location and time of the interview.			
Oral interview - Individual Post-submission theoretical and applied skills.	Demonstrate excellent theoretical and applied knowledge retention after assignment submission. You must be able to correctly explain the theory and justify methods used in your submission including MATLAB code.	Demonstrate adequate knowledge retention. If a student fails to show adequate understanding of their assignment and its components, including MATLAB code, his/her overall mark for this assignment may be moderated down by a maximum of 20%.	Demonstrate inadequate knowledge retention. If a student does not attend the interview or fails to demonstrate fundamental knowledge of their submission and its components, including MATLAB code, his/her overall mark may be moderated down by up to 100%