EGB242 – Assignment 1 (25%)

Individual assignment

Released: Friday 14th March, 11:59pm (Week 3)

Due: Friday 11th April, 11:59pm (Week 7)

Context

Congratulations on landing a summer internship at BASA, Brisbane's premiere (and only) space agency! Although such an achievement warrants an extended celebration, the launch date of the MARS-242 mission is rapidly approaching.

This crewed mission will deliver astronauts into orbit around the red planet in preparation for permanent residence, and land a rover onto the Martian surface to capture photographs of the proposed settlement location. To ensure both the astronauts and their scientific instruments aboard the spacecraft can maintain contact with mission control on Earth, a communication system must be designed.

Your first placement at BASA will involve finalising the design of several components of the communication system presented in Figure 1. You must detail your design process as part of a report to be presented to your supervisor, the head of communications engineering.

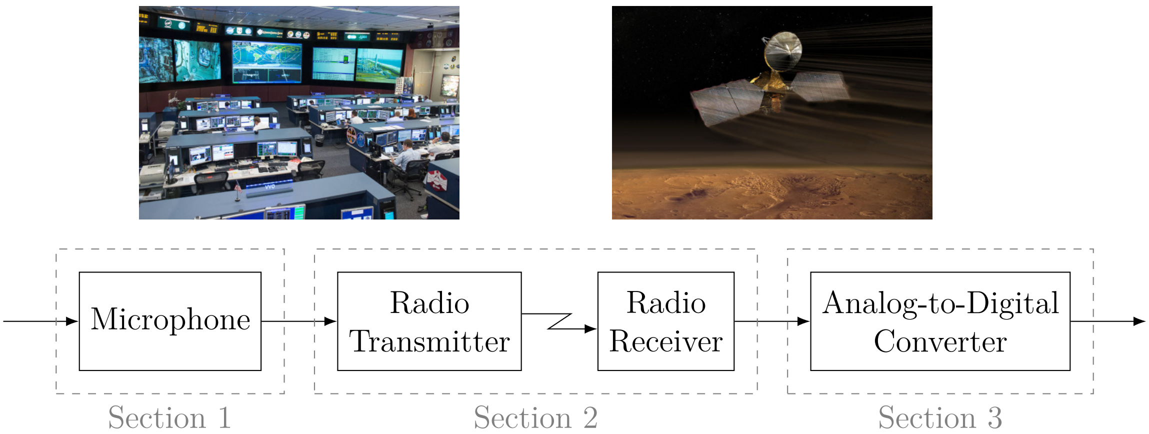

Figure 1: The communication system.

The system takes audio input through a microphone installed at mission control and uses a radio transmitter to send the audio signal to the astronauts. On the orbiter, a radio receiver will recover the audio signal which can then be prepared for digitisation by an analog-to-digital converter.

Academic Integrity

BASA insists on abiding by the academic integrity rules to ensure the competence and confidence in its engineers' knowledge, and the safety of the Astronauts.

The use of generative artificial intelligence (AI) tools, such as ChatGPT, is not permitted in this task. The use of such tools may be treated as a breach of the Academic Integrity Policy and appropriate penalties imposed.

Section 1: Removing Periodic Noise

After inspecting the audio waveform produced by the newly installed microphone at mission control, it has been observed that a periodic signal produced by other nearby equipment is causing significant interference. Through discussions with the engineer who designed the problematic equipment, a function which describes the noise and a model for the noise process have been developed. This will be useful in removing the interfering noise.

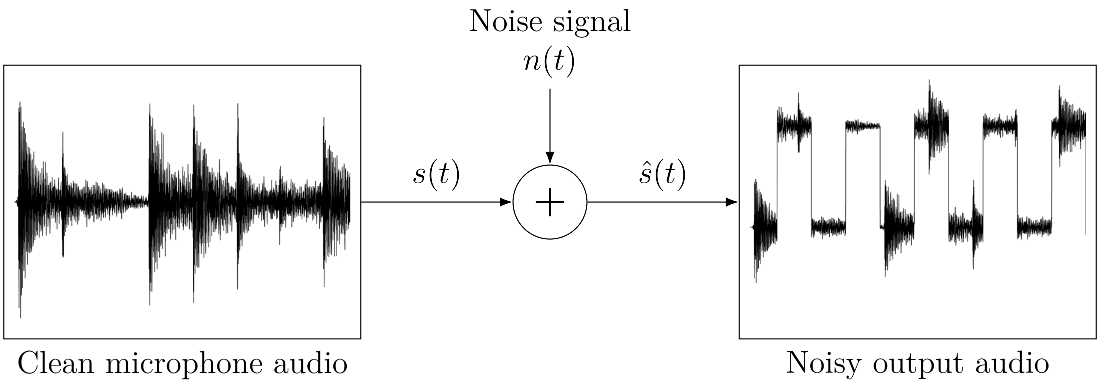

Figure 2: The additive noise model.

The interference of the periodic signal with the recorded audio can be modelled as an additive noise process (Figure 2). In order to produce clean, noise-free audio, this noise process must be reversed. Your task is to model the noise signal as a complex Fourier series, and use a Fourier series approximation to de-noise the signal.

1.1 Record 10 seconds of test audio and note down your noise function. To record your test audio, use the `record242` function from the MATLAB Command Window:

```
record242(sid)
```

where `sid` is replaced with your student number. Record the following message when prompted:

"Go for main engine start. T minus ten, nine, eight; All three engines up and burning. Two, one, zero, and liftoff!"

After recording your audio, write down the noise function $n\left(t\right)$ which is displayed. Ensure that the file `DataA1.mat` has been created.

You will only need to complete this step once.

1.2 Begin your MATLAB solution in the provided `missionA1.m` template. Listen to your recorded audio which has been loaded into the workspace with the `load DataA1` command by using `sound(audio, fs)`. Comment on your observations.

Note: you can stop a sound started with `sound()` *from playing by typing* `clear sound` *into the MATLAB Command Window.*

1.3 Create a time vector `t` for the audio signal. Plot the audio signal against `t`. Comment on your observations, and how they relate to any audible characteristics of the signal.

1.4 By hand, evaluate the complex Fourier series coefficients of your noise function. Typeset the noise function $n\left(t\right)$ and its complex Fourier series (including expressions for c_0 and c_n) into the body of your report. **Attach your hand-working as an appendix to your report**.

1.5 Using $-5 \leq n \leq 5$ (i.e., 5 harmonics), generate a vector cn in MATLAB **using your hand-working** which contains c_n evaluated at each value of n. List the values of these coefficients in your report.

1.6 Using the cn vector, generate an approximation of the noise signal nApprox for the full time vector t. Plot your recorded audio and your generated noise signal approximation.

1.7 De-noise the recorded audio by reversing the additive noise process (Figure 2) using your Fourier series approximation, and store the de-noised signal in audioClean. Listen to the clean signal, and plot it. Note any changes between the de-noised signal and the original corrupted audio.

1.8 Is using 5 harmonics in your noise signal approximation enough to adequately de-noise the audio? Experiment with the number of harmonics to determine a suitable value, and justify your choice both qualitatively and quantitatively.

Section 2: Transmitting and Receiving Signals

With the microphone audio now de-noised, it is ready to be fed into the radio transmitter and sent from the ground station to the MARS-242 orbiter. In order to transmit the signal, it must be modulated onto a carrier.

Modulation is the process of "moving" a signal in the frequency domain. It is only possible to transmit an audio signal as a radio wave once it is modulated and thus shifted to a much higher band of frequencies. However, this requires the shift to be removed when the radio wave is received in order to recover the audio signal. The *modulation property* of the Fourier transform allows these signal analysis processes to be achieved.

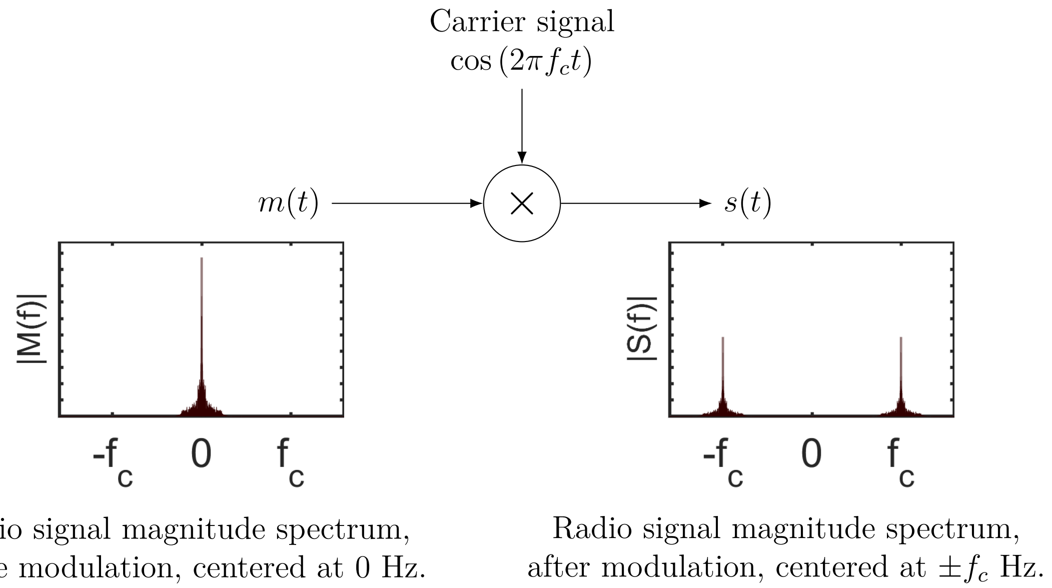

Figure 3: Using the modulation property to move a signal up to a carrier frequency of f_c Hz.

You have also been provided with a MATLAB function channel which simulates the transmission of a signal input between the ground station and the orbiter. The function is utilised as follows:

output = channel(sid, input);

where sid is your student number, input is a row vector representing the signal which should be transmitted, and output is the signal received by the orbiter.

2.1 Plot the magnitude spectrum of the clean audio signal, using an appropriate frequency vector f.

2.2 Observe the channel before transmitting your signal through it. You can observe the channel before transmitting anything by passing a vector of zeroes through the channel function.

channelQuiet = channel(sid, zeros(size(t)));

2.3 Before transmitting your modulated signal, you must determine a suitable center frequency not currently occupied by other signals on the channel. Plot the time and frequency domain of channelQuiet in order to find an empty band of frequencies that you can transmit your audio on. State your selected range of frequencies for this channel and the center frequency. Justify these parameter choices.

2.4 Modulate your audio signal using the carrier frequency you have selected.

2.5 Simulate the transmission of your modulated signal, providing it as input to the channel function, and plot the frequency domain representations of the input and output signals.

2.6 Demodulate your audio signal from the channel output created in 2.5. View the demodulated signal in the frequency domain. Filter the demodulated signal to isolate your audio signal. Use the lowpass function in MATLAB to simulate an analogue filter, and store the received audio as audioReceived. Discuss any additional factors that would need to be considered if using a real filter instead of the MATLAB lowpass function.

2.7 From your investigation of the frequency spectrum of the channel in 2.2, you will find other signals being transmitted over the channel. Modify your code to instead demodulate and filter each of the other signals visible in the channel and identify these signals.

Note: revert the changes you have made in 2.7 before proceeding.

Section 3: Analog-to-Digital Conversion

Although the demodulation process now allows the crew to listen to transmissions from an analogue speaker, a digital audio signal is required to distribute audio to the astronauts' headphones and other space ship systems. Thus, the signal must be digitised through a sampling and quantisation process.

3.1 Select the lowest sampling rate from Table 1 which is appropriate for the received signal, and justify your choice. Store your new sampling rate as fs2. Use MATLAB's resample function to resample your received audio signal, and store your resampled audio as audioResampled.

Although theoretically any positive number is a valid sampling rate, digital systems have settled on a common list of sampling rates which are most likely to be supported by hardware, shown in Table 1.

Table 1: Valid sampling rates, known to be widely supported by computer systems.

Valid sampling rates [Hz]							
5,512	8,000	11,025	22,050	44,100	48,000	96,000	192,000

3.2 Listen to and comment on the resampled audio.

3.3 With an appropriate quantiser (mid-tread or mid-riser), quantise audioResampled using 16 quantisation levels and store the result as audioQuantised. Listen to and plot the quantised audio and comment on any changes.

3.4 Experiment with using 2, 4, 8 and 32 quantisation levels. Listen to the quantised audio for each case, and select an appropriate number of quantisation levels for the final system.

3.5 To avoid causing interruptions to critical spaceship systems, BASA has specified that the internal communications system must not exceed 90kbits/s. Discuss how this constraint might affect your current design and provide alternative recommendations if necessary.

Reflection

A two paragraph reflection is to be written and appended at the end of your report. In the first paragraph, summarise how you have 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 the reflection are included as part of the CRA sheet on Canvas.

Report Length

Whilst no official page limit has been designated for this report, it is essential for professional engineering communication to be clear and **concise**. Overly verbose submissions may receive a deduction of marks for not meeting this requirement. Approximately 3-5 pages per question may be used as a rough guide. It is important to emphasise that **more is not better!** Longer submissions without the substance and clarity to justify the increased length of the report may lose marks for failing to be concise and failing to conform to the conventions of professional engineering presentation. Longer submissions may be acceptable through the use of meaningful figures and code snippets, though all figures, code, and tables must be fully described in the main body of the report and appropriately captioned. It is the responsibility of the students to be thoughtful and critical of their writing and presentation to ensure final submission demonstrates sufficient understanding of the technical components of the unit whilst also being concise.

Submission Requirements

This assignment is eligible for the 48-hour late submission extension. (This is an assignment for the purposes of an extension)

There are several components of Assignment 1 which must be submitted to the "Assessment 1 – Problem Solving Task: Submission" assignment on Canvas before the due date.

- Your report, in PDF format
- Your complete MATLAB solution (missionA1.m)
- Your recorded test audio (DataA1.mat)

These should be submitted as individual files and not as a Zip file.

After submitting, re-download each file to ensure you have submitted a complete and correct version of your assignment.

Report

To present your solution to the assignment tasks, you are required to write a report.

Your report should demonstrate clear knowledge and understanding of the subject through a combination of visual, mathematical, and coding elements. Your report should have a logical flow which guides the reader through your solution process, incorporating relevant explanations and justifications for the steps taken. Correct information which is not articulated clearly will be awarded a lower grade, as will inaccurate or vague justification. Ensure you include, at minimum, all requested plots/figures and justification. **Remember that you are writing to inform.**

It is highly recommended to follow the below report structure. You may adapt the structure to suit your needs, but ensure you include all required aspects.

- Title page - *must state your name, student number, the unit name and unit code*
- Introduction
- *Further headings, splitting up your solution as appropriate*
- Conclusion
- Reflection
- References - *if required*
- Appendices
  1. Full MATLAB source code - *include only raw source code, no figures*
  2. *Any other appendices as appropriate*

Note:

- Do not include a table of contents, list of figures, or a list of tables.
- Integrate code and figures throughout your report. Do not simply state "refer to appendix".

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 on Canvas for the guidelines of what is expected.