School of Science and Engineering

AL AKHAWAYN UNIVERSITY

LAB REPORT 1
CSC3371

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1. INTRODUCTION

This lab aims to give us hands-on experience with the basics of analog and digital modulation. By working through these experiments, we can better understand how modulation techniques work and see the effects in real-time. We'll use MATLAB and SIMULINK to simulate signals and study both amplitude modulation (AM) and quadrature phase shift keying (QPSK).

In this lab, we'll use MATLAB and SIMULINK to:

- Create and analyse message and carrier signals, then observe how they combine to form AM modulated and demodulated waveforms.
- Look at how adjusting the modulation index impacts the characteristics of an AM signal.
- Visualise the frequency spectrum of an AM signal to see its different components.
- Explore QPSK digital modulation to understand how it works, including the constellation diagram that represents signal phases.

The only equipment we need for this lab is a laptop with MATLAB and SIMULINK, which provide all the tools necessary for modelling and analysing these modulation techniques.

2. THEORETICAL BACKGROUND

Modulation is essential in communication systems, it enables efficient data transmission by embedding information within a carrier signal. This lab covers two key modulation types: **Amplitude Modulation (AM)** and **Quadrature Phase Shift Keying (QPSK)**.

Amplitude Modulation (AM)

In AM, the amplitude of a high-frequency carrier signal varies according to the information signal. Commonly used in radio, AM is simple and effective for transmitting audio. The AM signal is represented by:

$$s(t)=(1+u\cdot m(t))\cdot c(t)$$ where:

- m(t): Information signal with amplitude Am and frequency fm
- c(t): Carrier signal with amplitude Ac and frequency fc
- u=Am /Ac : Modulation index, determining modulation depth and signal clarity.
- If u is under 1, under-modulation occurs; if u is over 1, **over-modulation** leads to distortion.

The carrier wave is defined as:

$$c(t)= Ac\cos(2\pi fct)$$

The message signal is defined as:

$$m(t)= Am\cos(2\pi fmt)$$

Hence, the modulated signal is:

$$s(t)= (Ac+m(t)) \cos(2\pi fct)$$

3. EXPERIMENTAL PROCEDURES

Procedure 1: Amplitude Modulation using Matlab

1. We created an M-file
2. Name it Am.m

Type the following:

```
fs = 20*fc;
d = .05;
n = fs * d;
t = (1:n) / fs;
```

3. Create a sinusoidal signal with frequency $f_m = 50\ Hz$

```
fm = 50;
m = cos(2 * pi * fm * t);

plot(t,m,'gr','LineWidth',2);
title('Information Signal m(t)')
ylabel('Amplitude')
xlabel('Time')
```

4.From the menu bar at the top of the MATLAB command window, save your "File As" and type 'AM' for Example.

- To execute the m-file:
Go to the MATLAB command window. From the menu bar at the top, -> Click on "**Run**"

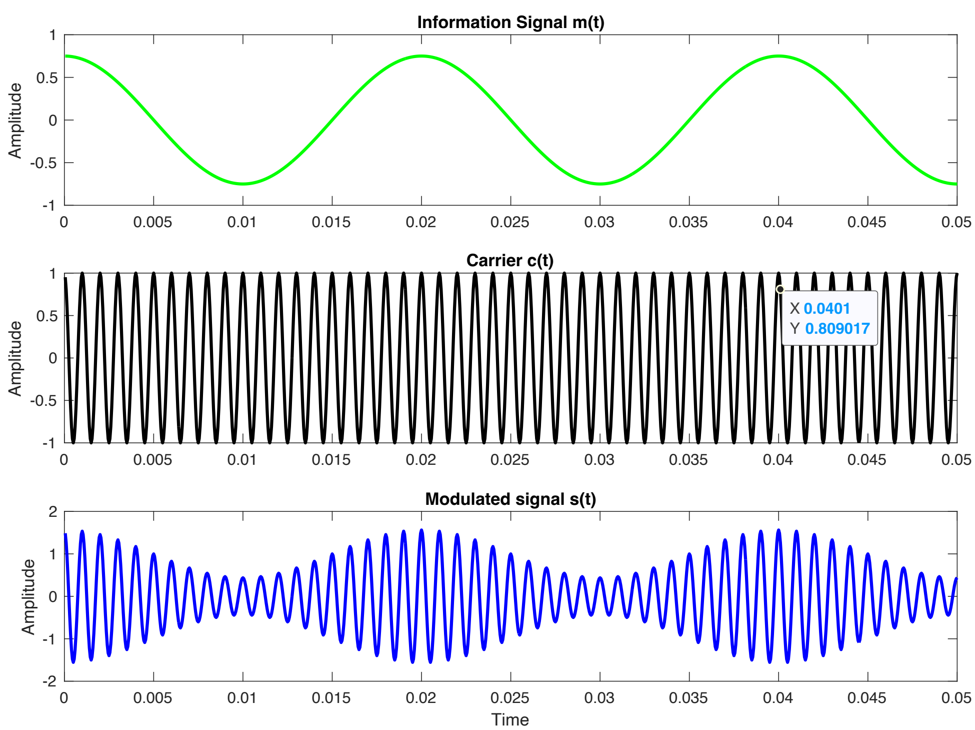
5. Now create the carrier; another sinusoidal signal c(t) with $fc = 1000\ Hz$.

```
fc = 1e3;
fs = 20*fc;
d = .05;
n = fs * d;
t = (1:n) / fs;
c = cos(2 * pi * fc * t);
plot(t,c);
plot(t,c,'k','LineWidth',2);
title('Carrier c(t)')
ylabel('Amplitude')
xlabel('Time')
```

6. Now create the amplitude modulated waveform with:

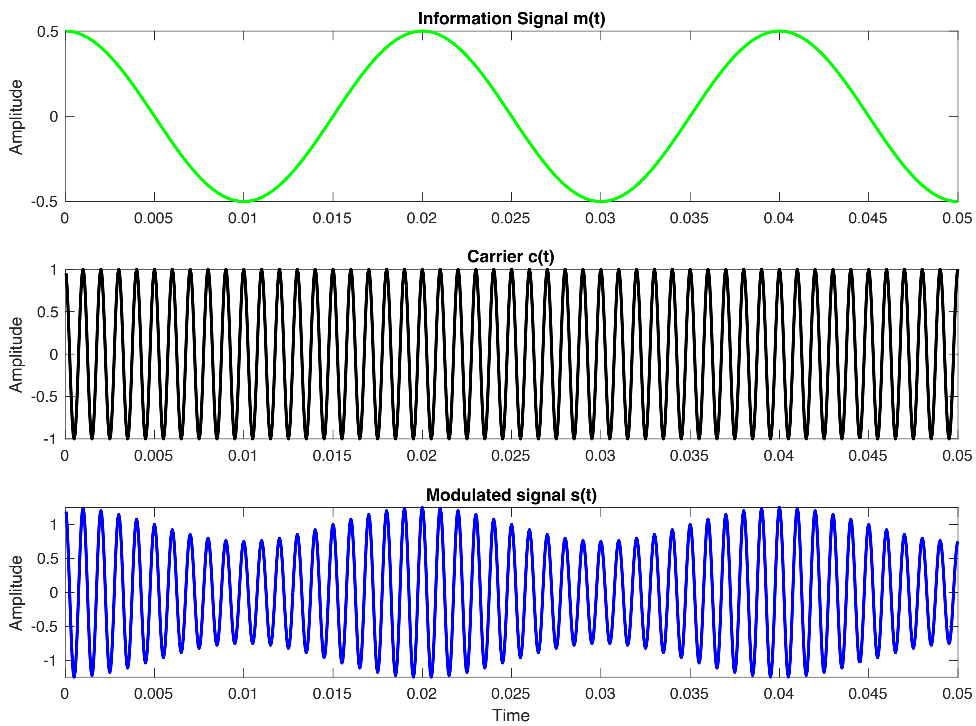
```
fc = 1e3;
fs = 20*fc;
d = .05;
n = fs * d;
t = (1:n) / fs;

fm=50;
Am=.75;
m =Am* cos(2 * pi * fm * t);

Ac=1;
c = Ac*cos(2 * pi * fc * t);
u=Am/Ac;
s  = (1+u*m) .* c;
```

Q1.1. Plot the AM signal.



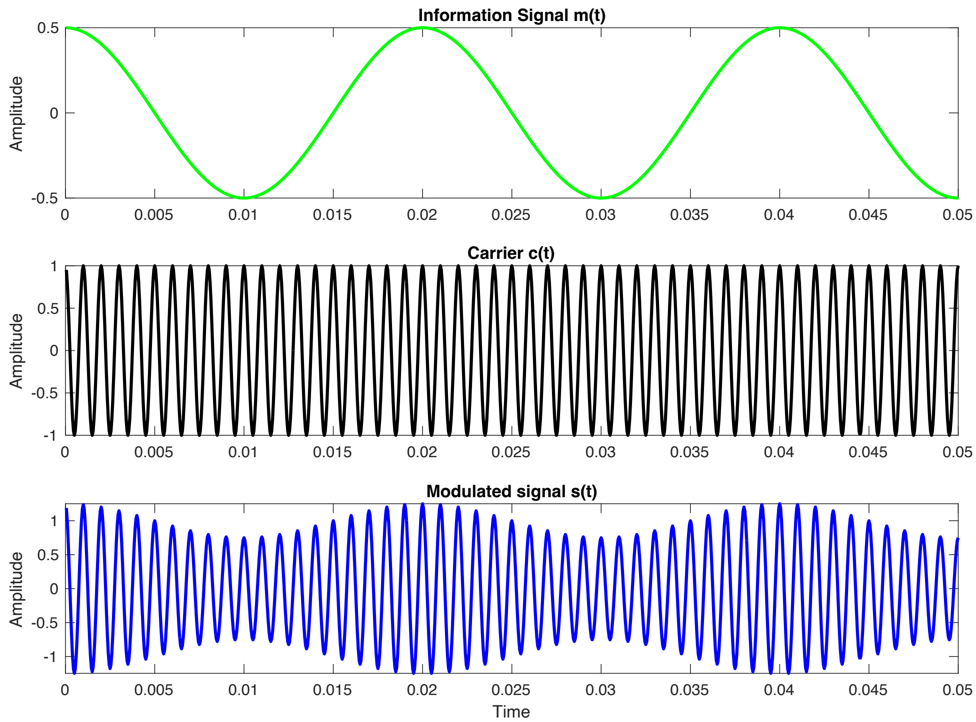
Q1.2. What happens if we choose Am to be 0.5 Volts? What is the percentage of modulation in this case? Plot the AM signal.

In this case of Am =0.5 Volts, the maximum amplitude of the message (or modulating) signal is less than the maximum amplitude of the carrier signal, which results in "under-modulation." Here, the modulation percentage is 50%



Q1.3. What happens if we choose Am to be 1.5 Volts? What is the percentage of modulation in this case? Plot the AM signal and comment on your answers.

When we set Am to 1.5 Volts, the signal enters what's known as an "over-modulation" state, with a modulation level of 150%. Here, the modulating signal's amplitude is higher than that of the carrier signal, which causes distortion in the AM waveform. This distortion can lead to errors in the transmitted information, as the signal becomes less accurate.



Procedure 2: Amplitude Modulation using SIMULINK.

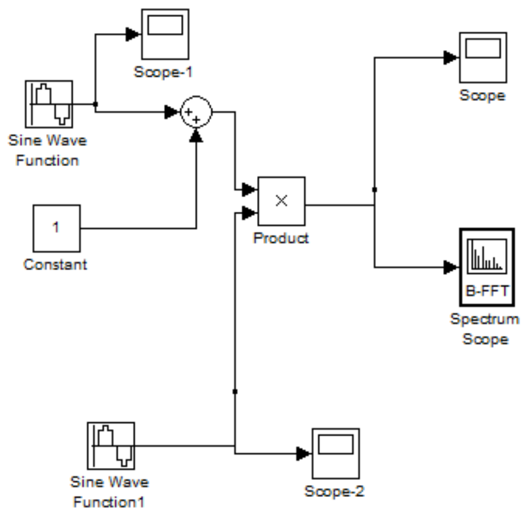
First start new model.

We need to build the following function.

$$s_{AM}(t) = A_c[1 + \mu \cos \omega_m t]\cos \omega_c t$$

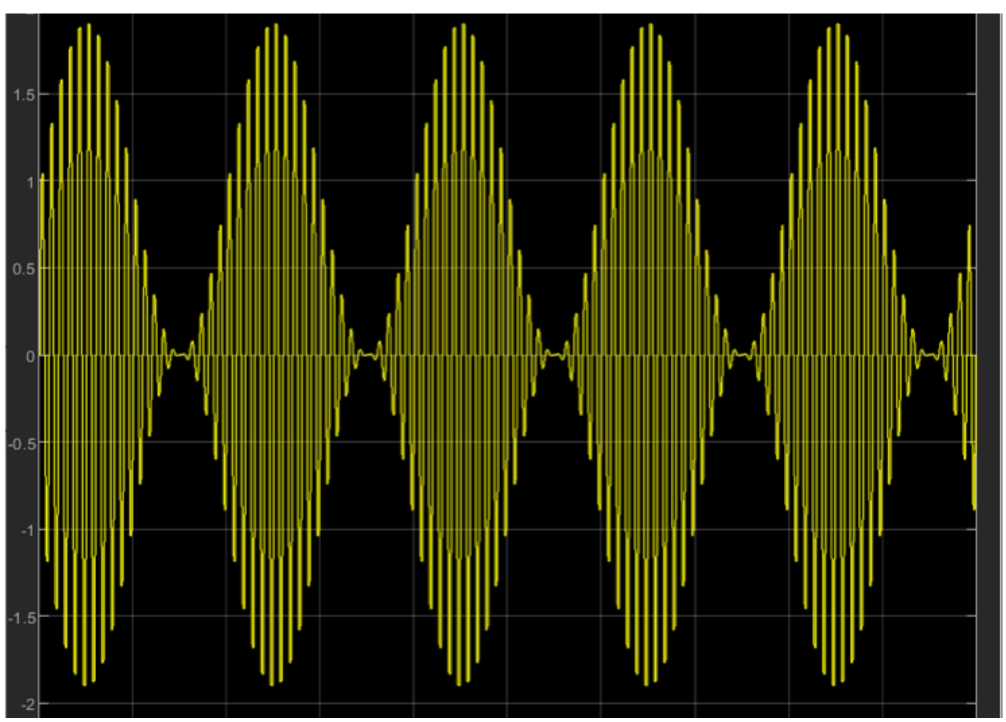
Where m(t) is a sinusoidal function.

We need two cosine waveforms and a constant.

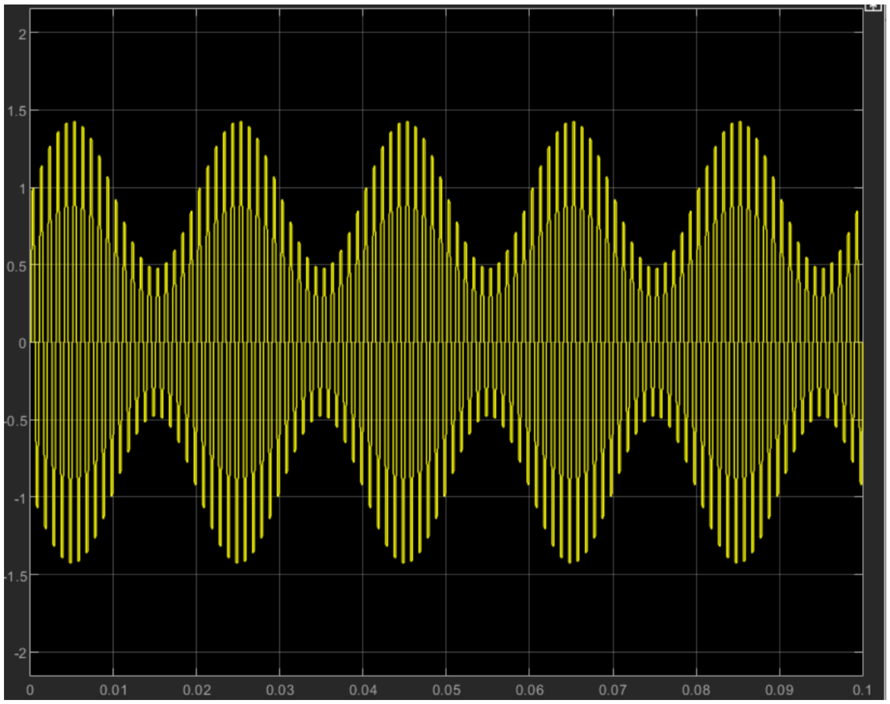


We built this model

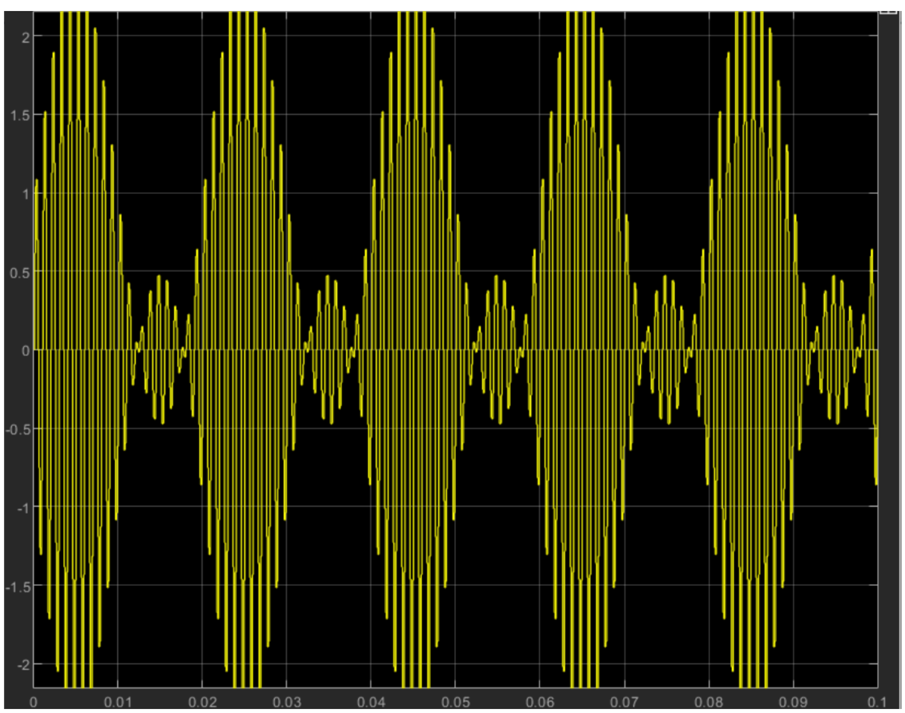
Q2.1- Repeat Q1.1 to Q1.3 using SIMULINK



Scope 1: AM modulation with modulation index of 1



Scope 2: AM modulation with modulation index of 0.5

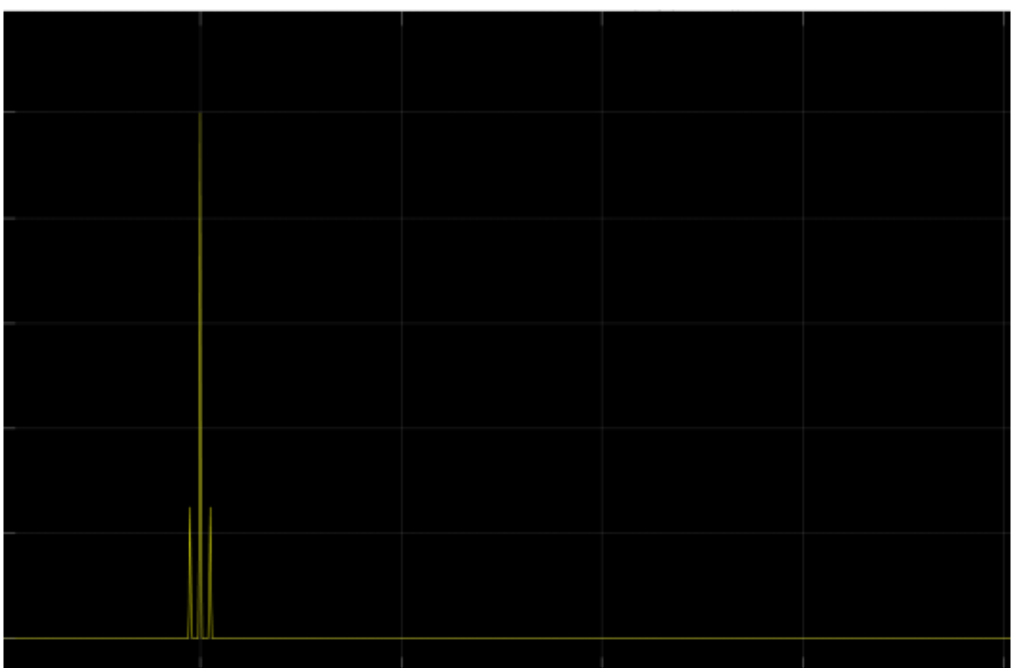


Scope 3: AM modulation with modulation index of 1.5

After repeating the same approach of first question, we receive the same results but different AM values. In Scope 1, we got Perfect Modulation, in Scope 2, we got No Distortion, while in Scope 3, we have Over-modulation.

These scopes shows that the value of the modulating signal varies depends on the amplitude of the message signal, which changes the modulation index.

Q2.2- Plot the spectrum for s(t) using SIMULINK.



Amplitude Modulation: $Am = 1, Ac = 1.$

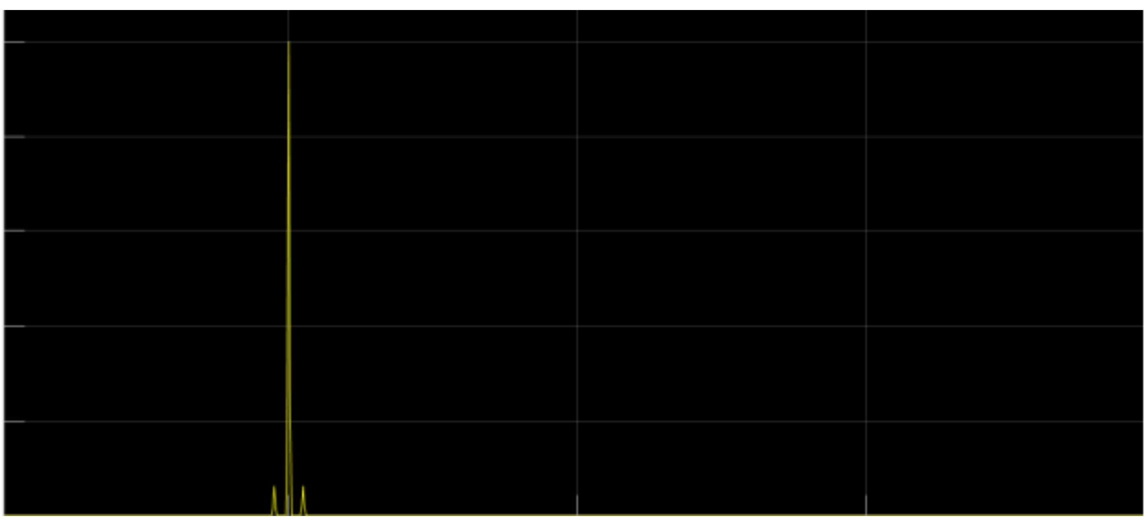
For the frequency spectrum, we have 3 peaks:

1. At f = $fc - fm$ = 950Hz t

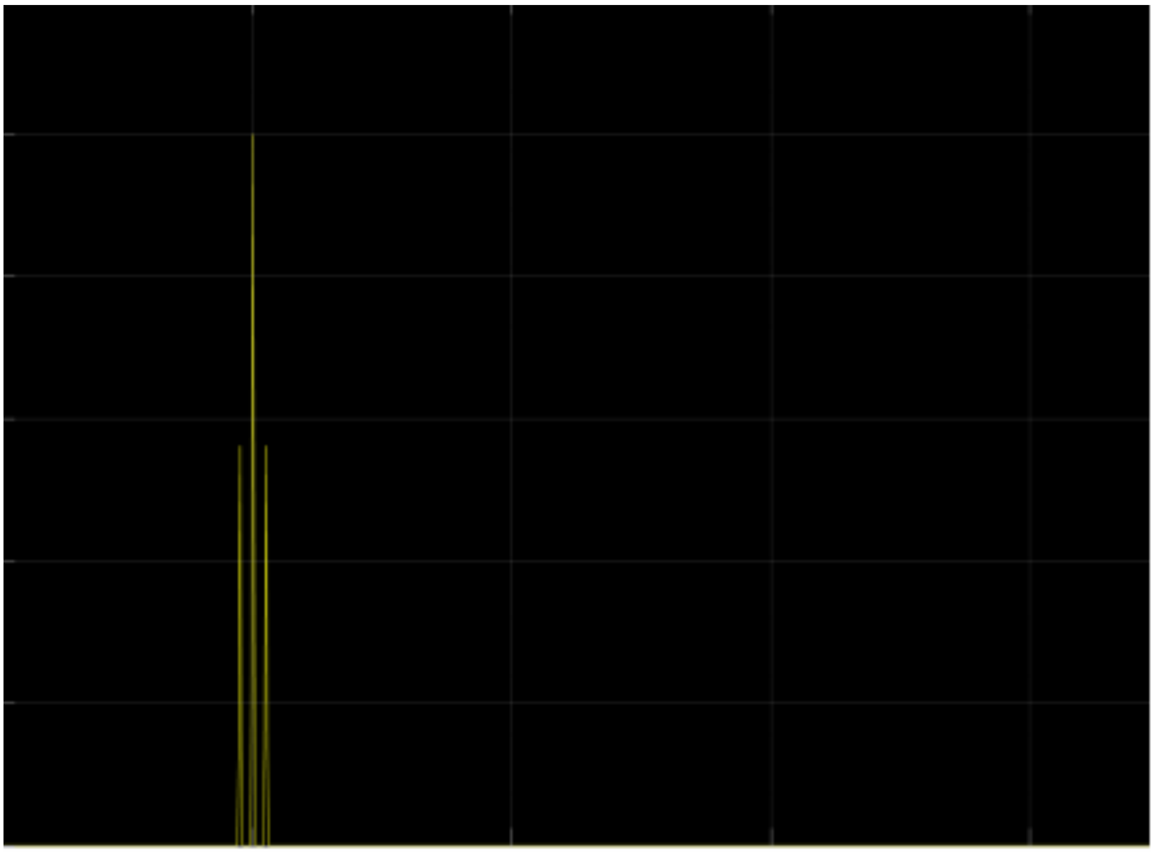
2. At f = fc = 1000Hz

3. At f = $fc + fm$ = 1050Hz

The peaks at $f_c - f_m$ and $f_c + f_m$ represent the LSB and USB respectively.



Amplitude Modulation: Am = 0.5, Ac = 1.



Amplitude Modulation: $Am = 1.5$, $Ac = 1$.

4. ANALYSIS AND DISCUSSION

The experiments conducted in MATLAB and SIMULINK allowed for a detailed examination of amplitude modulation (AM) under different modulation levels. The results helped us understand the effects of varying the modulation index on signal quality and the presence of distortion.

Procedure 1: Amplitude Modulation in MATLAB

In MATLAB, we created AM signals with different values of the modulation index by adjusting the amplitude of the message signal (Am). Observing these AM signals at various levels of modulation demonstrated the key characteristics of under-modulation, standard modulation, and over-modulation.

Table 1: AM Signal Characteristics in MATLAB

Amplitude of Message Signal (Am)	Modulation Index (u)	Modulation Percentage	Results
0.5 V	0.5	50%	Under Modulation
0.75 V	0.75	100%	Standard Modulation
1.5 V	1.5	150%	Over Modulation

The table above summarises the modulation characteristics observed in MATLAB:

1. **Under-Modulation (Am = 0.5 V)**: With a modulation index of 0.5 (50%), the AM waveform was clear but displayed a reduced envelope depth, as the message signal's amplitude was lower than the carrier's. This results in a weaker signal with less effective data transmission.

2. **Standard Modulation (Am = 0.75 V)**: At a modulation index of 0.75 (75%), the waveform displayed a well-balanced AM signal with no distortion, making it an ideal modulation level for clarity and efficiency.

3. **Over-Modulation (Am = 1.5 V)**: When Am was increased to 1.5 V, the modulation index became 1.5 (150%). This excessive modulation causes signal distortion.

Procedure 2: Amplitude Modulation in SIMULINK

Using SIMULINK, we repeated the AM modulation process and observed the resulting waveforms in real-time through scope displays. The observations were consistent with the MATLAB results, confirming the effects of each modulation level.

Scope	Modulation Level	Observation
Scope 1	Standard Modulation (Am = 0.75 V)	clear AM waveform
Scope 2	Under-Modulation (Am = 0.5 V)	clear waveform but weaker amplitude
Scope 3	Over-Modulation (Am = 1.5 V)	clear waveform but weaker amplitude

In SIMULINK, each scope provided insight into the behaviour of the AM waveform at various modulation levels:

- **Scope 1** showed a well-modulated signal without distortion.
- **Scope 2** shows that under-modulation resulted in a clear but less intense signal.
- **Scope 3** displayed the impact of over-modulation, showing how excessive modulation causes distortion.

Frequency Spectrum Analysis

The spectrum exhibited peaks at the following frequencies:

Frequency Hz	Description
950 Hz	Lower Side Band LSB
1000 Hz	Carrier Frequency
1050 Hz	Upper Side Band USB

These frequencies correspond to the carrier and sidebands, which carry the information signal:

- **Carrier Frequency (1000 Hz)**: The main frequency used to transmit the signal.
- **Sidebands (950 Hz and 1050 Hz)**: Represent the information signal at frequencies fc−fm and fc+fm , confirming the modulation's success in embedding the message signal within the carrier.

This analysis shows the importance of selecting the correct modulation level for reliable and efficient signal transmission. The tables above summarise the key observations and results from both MATLAB and SIMULINK analyses, and confirms that an optimal modulation index is crucial to avoiding distortion and maintaining signal clarity.

5. CONCLUSION

This lab demonstrated the impact of varying the modulation index in amplitude modulation (AM) and reinforced key concepts using MATLAB and SIMULINK, also understanding QPSK.

parameters that affect signal quality, such as the modulation index

Key Findings:

- **Under-Modulation (Am = 0.5 V, 50%)**: Produced a clear but weaker signal with reduced envelope depth.
- **Standard Modulation (Am = 0.75 V, 75%)**: Provided an ideal, balanced AM waveform with no distortion.
- **Over-Modulation (Am = 1.5 V, 150%)**: Caused envelope overlap and distortion, showing the need to avoid high modulation levels.

SIMULINK Observations:

- Scope displays in SIMULINK confirmed MATLAB results: under-modulation showed a weaker signal, standard modulation was clear and balanced, and over-modulation led to distortion.

Frequency Spectrum Analysis:

- The frequency spectrum confirmed successful data embedding, with visible peaks at the carrier frequency and sidebands (950 Hz and 1050 Hz).

Recommendations:

- **Optimal Modulation Index**: Keep the modulation index around 0.75 to ensure clear, distortion-free transmission.
- **Noise Testing**: add noise in future experiments to assess AM signal robustness under real-world conditions, to provide insights into AM's resilience in noisy environments
- **Practical Applications**: Test AM signals with varying modulation indices in practical applications, to assess real-world effectiveness.

Overall, careful modulation control is essential for effective AM transmission. MATLAB and SIMULINK proved to be valuable tools for visualising and understanding AM signal characteristics.

6. REFERENCES

[1] https://matlab.mathworks.com/
[2] https://www.analog.com/en/resources/glossary/qpsk.html#:~:text=Definition,PSK%20using%20the%20same%20bandwidth.
[3] https://www.geeksforgeeks.org/amplitude-modulation-definition-types-expression/