1 Experiment No. 2

2 Experiment Title

Observation & Verification of Amplitude Modulation & Demodulation

3 Objective

The objectives of this lab are as follows:

- To explore the practical implementation and circuit configurations of modulation and demodulation kits
- To understand the working principles of modulation and demodulation techniques

4 Theory

4.1 Amplitude Modulation

In AM, the amplitude of the carrier signal is modulated by the message signal, while the frequency and phase of the carrier remain constant. Let's define the key signals involved:

1. **Message Signal**: The information signal to be transmitted, denoted as $m(t)$. Typically, it is a low-frequency signal, e.g., an audio signal.
2. **Carrier Signal**: A high-frequency sinusoidal signal, denoted as $c(t) = A_c \cos(2\pi f_c t)$, where A_c is the carrier amplitude and f_c is the carrier frequency.
3. **Modulated Signal**: The resulting AM signal, denoted as $s(t)$.

4.2 Modulation Process

The AM signal is generated by multiplying the carrier signal by a term that includes the message signal. The general expression for the AM signal is:

$$s(t) = [A_c + m(t)] \cos(2\pi f_c t) \tag{1}$$

To normalize the modulation, the message signal is often scaled by the modulation index m, defined as:

$$m = \frac{A_m}{A_c} \tag{2}$$

where A_m is the peak amplitude of the message signal $m(t)$. Assuming $m(t) = A_m \cos(2\pi f_m t)$, where f_m is the message signal frequency, the AM signal becomes:

$$s(t) = A_c [1 + m \cos(2\pi f_m t)] \cos(2\pi f_c t) \tag{3}$$

Expanding this using the trigonometric identity $\cos A \cos B = \frac{1}{2}[\cos(A + B) + \cos(A - B)]$, we get:

$$s(t) = A_c \cos(2\pi f_c t) + \frac{mA_c}{2} \cos[2\pi(f_c + f_m)t] + \frac{mA_c}{2} \cos[2\pi(f_c - f_m)t] \quad (4)$$

This shows that the AM signal consists of:

- The carrier component at frequency f_c.
- The upper side-band at $f_c + f_m$.
- The lower side-band at $f_c - f_m$.

4.3 Modulation Index

The modulation index m determines the extent of modulation:

1. **Under-modulation** ($m < 1$): The envelope of the AM signal follows the message signal without distortion.
2. **Full modulation** ($m = 1$): The carrier amplitude varies between 0 and $2A_c$, maximizing the side-band power without distortion.
3. **Over-modulation** ($m > 1$): The envelope becomes distorted, leading to signal clipping and recovery challenges during demodulation.

4.4 Amplitude Demodulation

Demodulation is the process of extracting the original message signal $m(t)$ from the AM signal $s(t)$. The most common method is **envelope detection**, which is simple and effective for standard AM signals.

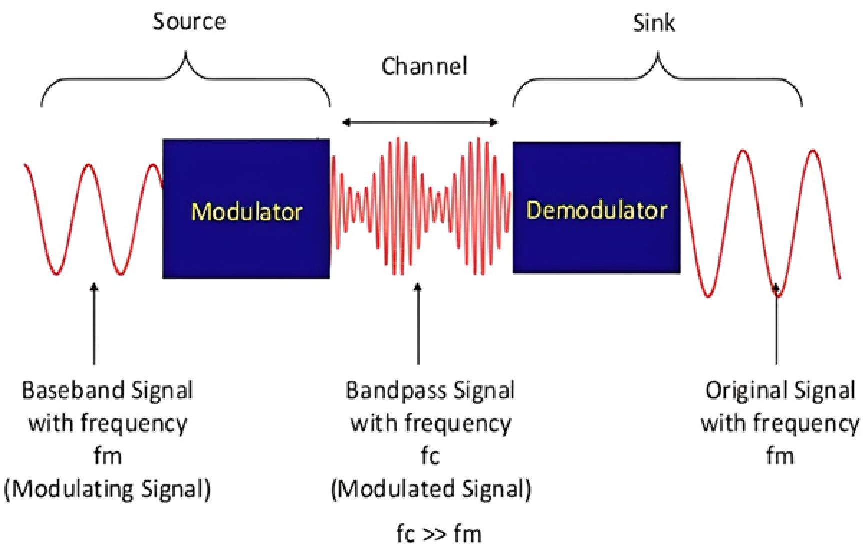


Figure 1: Demodulation process

4.5 Envelope Detection

The AM signal $s(t) = A_c [1 + m \cos(2\pi f_m t)] \cos(2\pi f_c t)$ has an envelope given by $A_c |1 + m \cos(2\pi f_m t)|$. The steps for envelope detection are:

1. **Rectification**: Pass the AM signal through a diode to obtain the positive portion, yielding $|s(t)|$.
2. **Low-pass filtering**: Apply a low-pass filter to remove the high-frequency carrier components, leaving the envelope $A_c[1 + m\cos(2\pi f_m t)]$.
3. **DC removal**: Subtract the DC component A_c (using a capacitor or high-pass filter) to recover $m(t)$.

Mathematically, the output of the envelope detector, after filtering, is proportional to:

$$m(t) = A_m \cos(2\pi f_m t) \tag{5}$$

4.6 Conditions for Successful Demodulation

For envelope detection to work effectively:

1. The modulation index should satisfy $m \leq 1$ to avoid distortion due to over-modulation.
2. The carrier frequency f_c must be much higher than the message frequency f_m ($f_c \gg f_m$) to ensure the envelope can be accurately tracked.

4.7 Required Apparatus

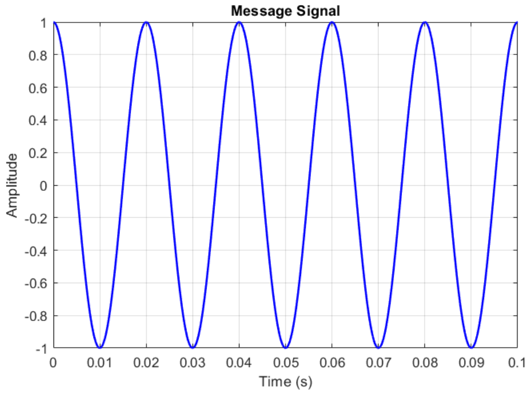
1. Amplitude modulation transmitter kit.
2. Amplitude Demodulator Receiver kit.
3. Connecting wires.

4.7.1 MATLAB Code:

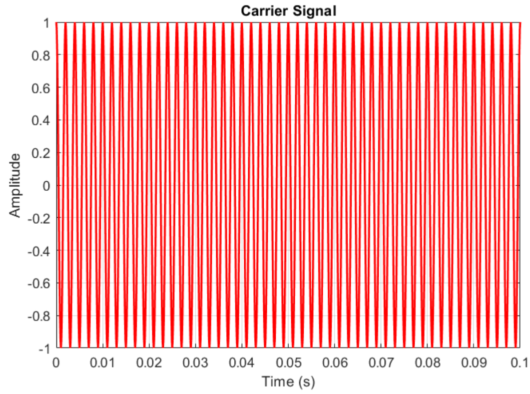
```
% MATLAB code for AM modulation with separate plots
% Message and carrier signals, and AM signals for under, full, and over modulation
clear all;
close all;
% Parameters
t = 0:0.0001:0.1; % Time vector (0 to 0.1s, 10001 samples)
fm = 50; % Message signal frequency (50 Hz)
fc = 500; % Carrier signal frequency (500 Hz)
Am = 1; % Message signal amplitude
Ac = 1; % Carrier signal amplitude

% Message and carrier signals
m_t = Am * cos(2 * pi * fm * t); % Message signal
c_t = Ac * cos(2 * pi * fc * t); % Carrier signal

% Modulation indices for under, full, and over modulation
m_indices = [0.5, 1, 1.5]; % m = 0.5 (under), 1 (full), 1.5 (over)

% Plot 1: Message Signal
figure('Position', [100, 100, 600, 400]);
plot(t, m_t, 'b', 'LineWidth', 1.5);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');
grid on;
set(gcf, 'Color', 'w');

% Plot 2: Carrier Signal
figure('Position', [750, 100, 600, 400]);
plot(t, c_t, 'r', 'LineWidth', 1.5);
title('Carrier Signal');
xlabel('Time (s)');
ylabel('Amplitude');
grid on;
set(gcf, 'Color', 'w');

% Plot AM signals for different modulation indices
for i = 1:length(m_indices)
m = m_indices(i);
s_t = (1 + m * m_t / Am) .* c_t; % AM signal: s(t) = [1 + m*m(t)/Am]*c(t)

% Create a new figure for each AM signal
figure('Position', [100 + (i-1)*650, 600, 600, 400]);
plot(t, s_t, 'k', 'LineWidth', 1.5);
title(['AM Signal (m = ', num2str(m), ')']);
xlabel('Time (s)');
ylabel('Amplitude');
grid on;
set(gcf, 'Color', 'w');
end
```

Listing 1: Solving Non-linear Equation Using Newton-Raphson Method in MATLAB.

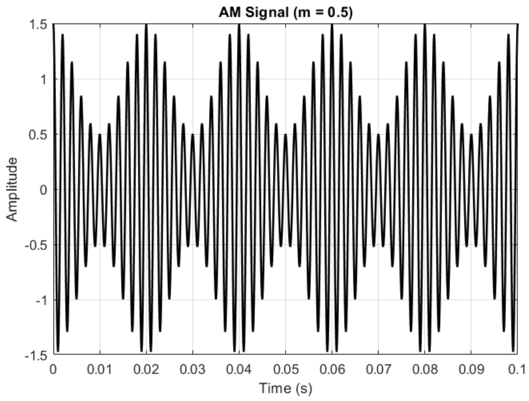
5 Plot Diagram



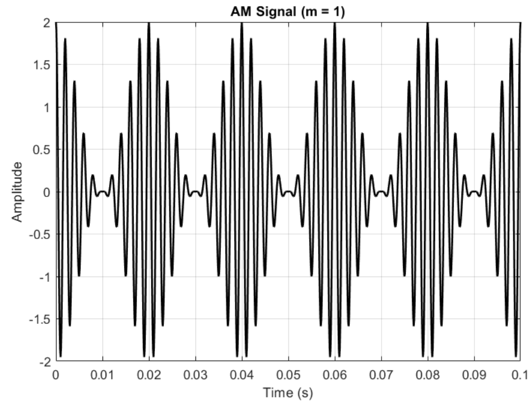
(a) Message Signal



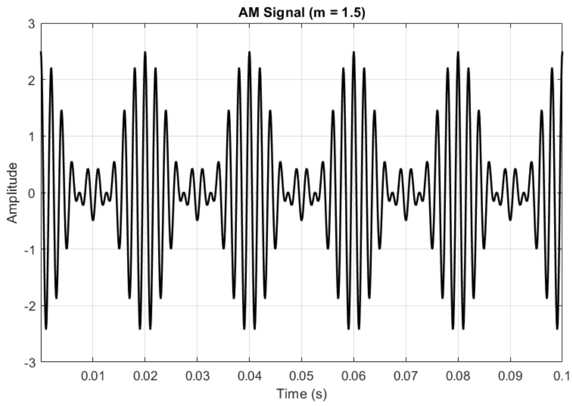
(b) Carrier Signal



(c) modulation index , m=0.5

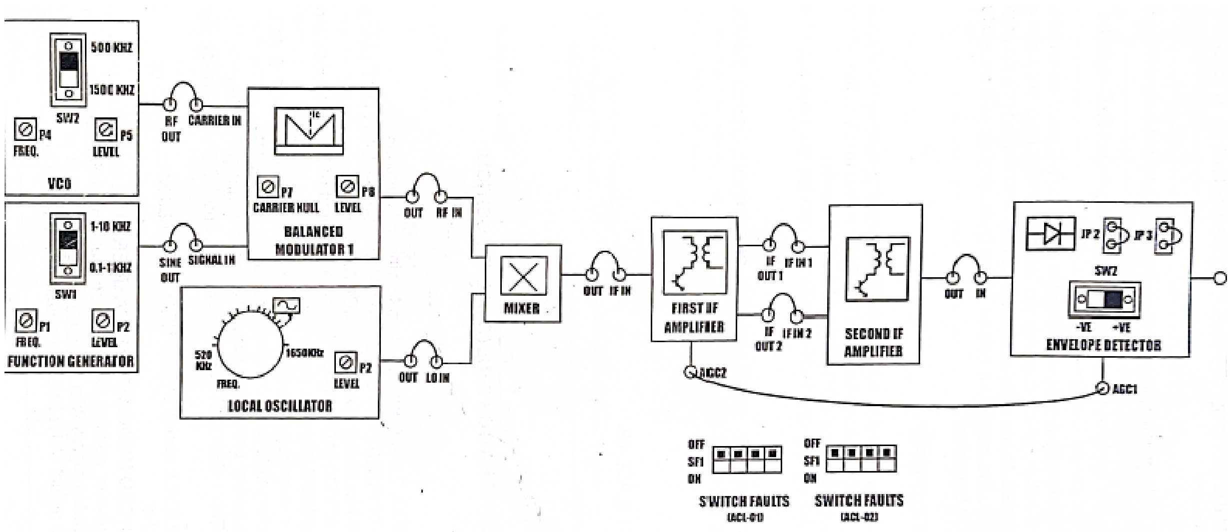


(d) modulation index , m=1

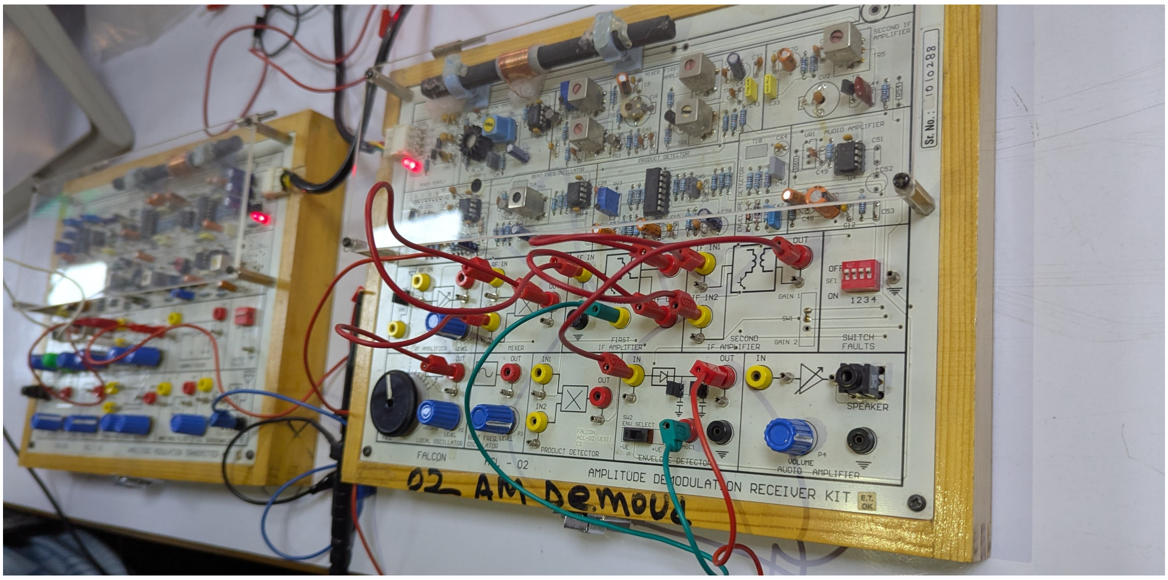


(e) modulation index , m=1.5

6 Experimental Setup



(a) Required circuit diagram



(b) Actual setup

7 Experimental Wavehape

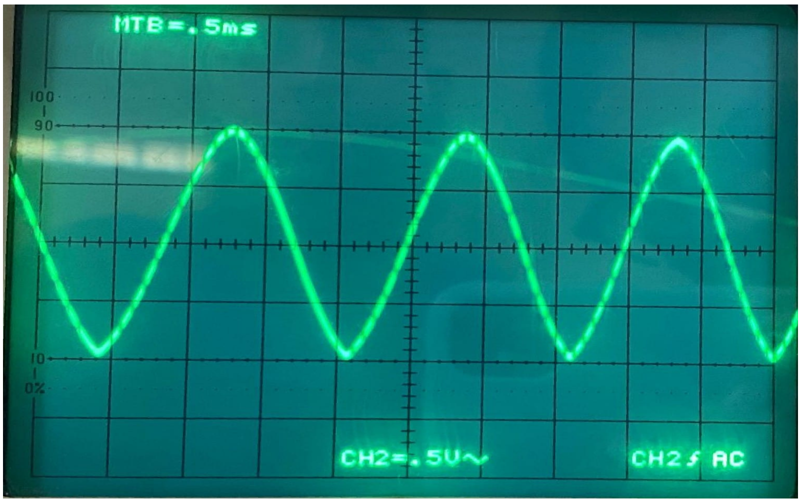


Figure 4: Message Signal

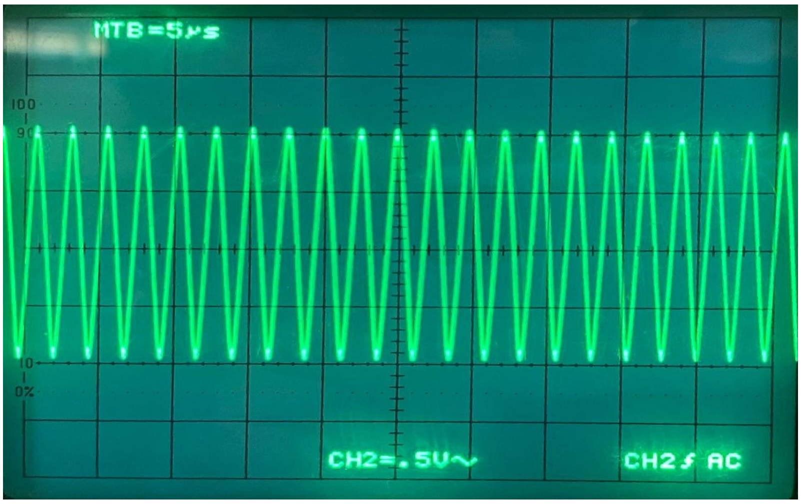


Figure 5: Carrier Signal

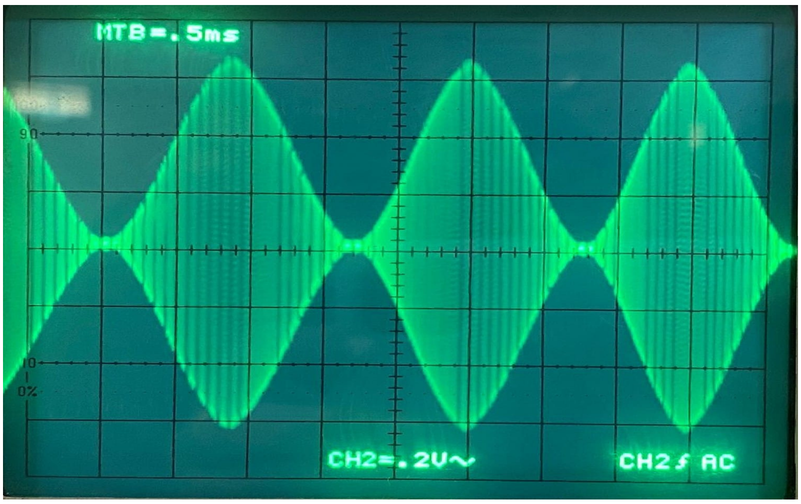


Figure 6: modulation index , m = 1

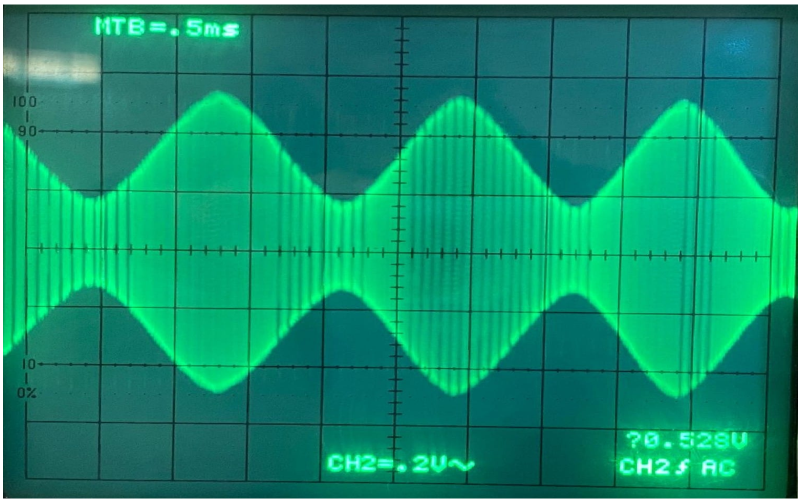


Figure 7: modulation index , m < 1

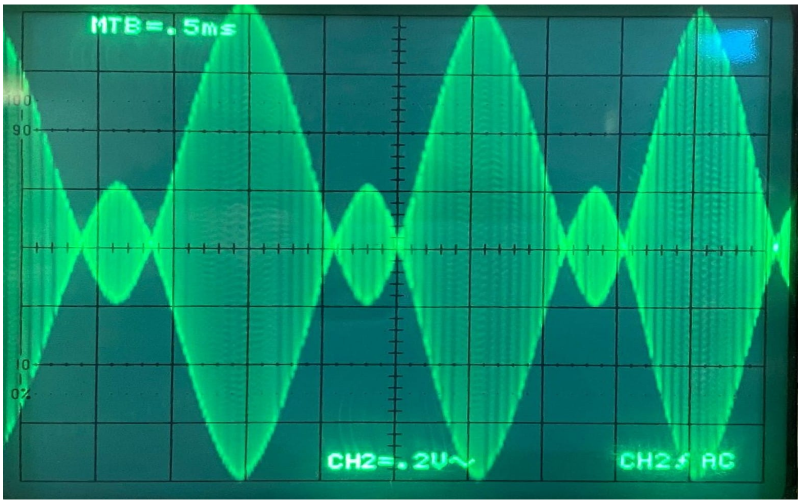


Figure 8: modulation index , m > 1

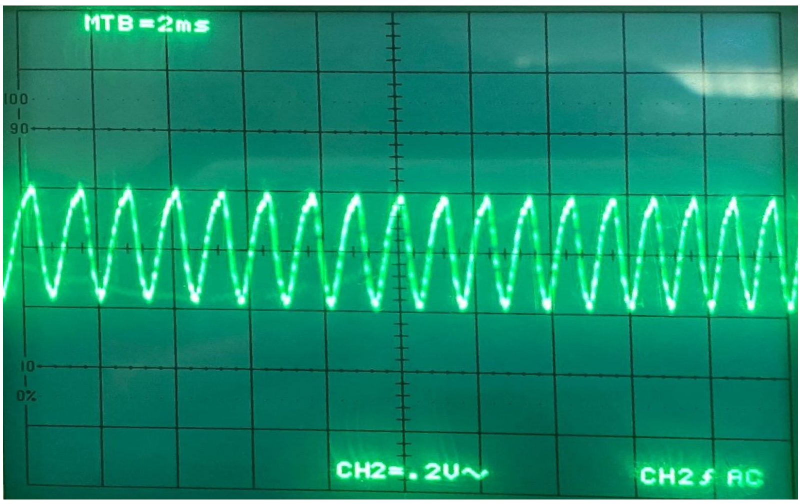


Figure 9: Demodulated Signal

8 Discussion

In the experiment, amplitude modulation and demodulation were observed using an amplitude-modulation transmitter kit and an amplitude-demodulation receiver kit. The transmitter circuit was assembled according to the manual, and both the message and carrier signals were generated. These two signals were combined to produce the modulated waveform. The modulated signal was then fed into the Demodulator kit, and the desired message signal was recovered at the output by use of the envelope detector.