1 Experiment No. 3

2 Experiment Title

Observation & Verification of Frequency Modulation and Demodulation

3 Objective

The objectives of this lab are as follows:

- To understand how the frequency of the carrier wave varies according to the message signal.
- To demodulate the FM signal and recover the original message signal.

4 Theory

4.1 Frequency Modulation (FM)

Frequency Modulation (FM) is a technique of modulating a carrier signal in which the frequency of the carrier wave is varied in accordance with the instantaneous amplitude of the modulating (message) signal, while its amplitude remains constant. The general expression for an FM signal is:

$$s(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int_0^t m(\tau) d\tau\right) \tag{1}$$

Where:

- A_c is the amplitude of the carrier signal
- f_c is the carrier frequency
- k_f is the frequency sensitivity (Hz/V)
- $m(t)$ is the modulating signal

The instantaneous frequency of the FM signal is given by:

$$f_i(t) = f_c + k_f m(t) \tag{2}$$

Thus, the frequency of the carrier varies with the amplitude of the input signal $m(t)$.

4.2 Modulation Index in FM

The modulation index (β) in FM is defined as the ratio of frequency deviation (Δf) to the modulating frequency (f_m):

$$\beta = \frac{\Delta f}{f_m} \tag{3}$$

4.3 Demodulation of FM Signal

FM demodulation is the process of recovering the original modulating signal from the frequency-modulated carrier. This can be achieved using different techniques such as:

- Frequency discriminator
- Phase-locked loop (PLL)

One common approach is using a frequency discriminator which converts frequency variations into amplitude variations, followed by an envelope detector to recover the original signal. Alternatively, a Phase-Locked Loop (PLL) based demodulator uses a voltage-controlled oscillator (VCO) that locks onto the frequency of the input FM signal and produces an output voltage proportional to the frequency deviation, hence reproducing the modulating signal.

4.4 Bandwidth of FM Signal

According to Carson's Rule, the bandwidth (B) required for an FM signal is given by:

$$B = 2(\Delta f + f_m) = 2f_m(\beta + 1) \tag{4}$$

This shows that FM requires a wider bandwidth than AM, especially when the modulation index is large.

4.5 Required Apparatus

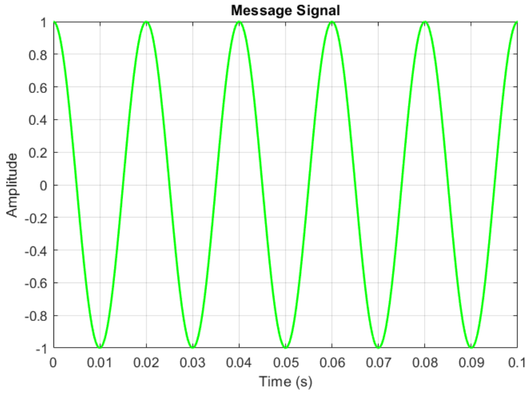
1. DCTK-1000 & ACTK-1000 kit.
2. Digital Oscilloscope (TBS-1000c).
3. Connecting wires & Probes.

4.5.1 MATLAB Code:

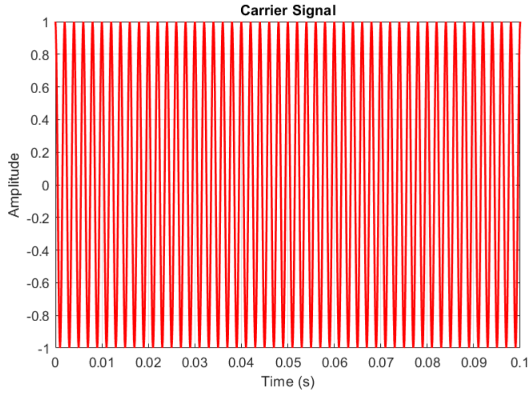
```
clear all;
close all;

% Parameters
t = 0:0.0001:0.1;        % Time vector
fm = 50;                 % Message signal frequency (Hz)
fc = 500;                % Carrier signal frequency (Hz)
Am = 1;                  % Message amplitude
Ac = 1;                  % Carrier amplitude
kf = 100;                % Frequency sensitivity (Hz/V)

% Message Signal
m_t = Am * cos(2 * pi * fm * t);

% Carrier Signal
c_t = Ac * cos(2 * pi * fc * t);

% Frequency Modulated Signal
dt = t(2) - t(1);
int_m_t = cumsum(m_t) * dt; % Integration of message signal
s_fm = Ac * cos(2 * pi * fc * t + 2 * pi * kf * int_m_t); % FM signal

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

% Plot Carrier Signal (Red)
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 FM Signal (Black)
figure('Position', [400, 550, 600, 400]);
plot(t, s_fm, 'k', 'LineWidth', 1.5);
title('Frequency Modulated (FM) Signal');
xlabel('Time (s)');
ylabel('Amplitude');
grid on;
set(gcf, 'Color', 'w');
```

Listing 1: Frequency Modulation.

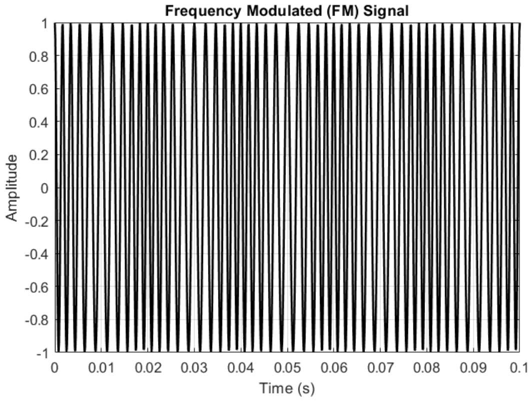
5 Plot Diagram



(a) Message Signal

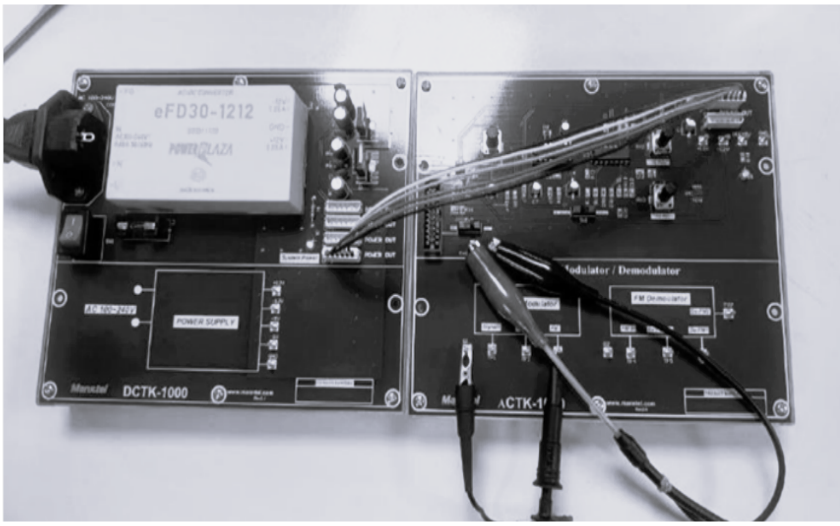


(b) Carrier Signal

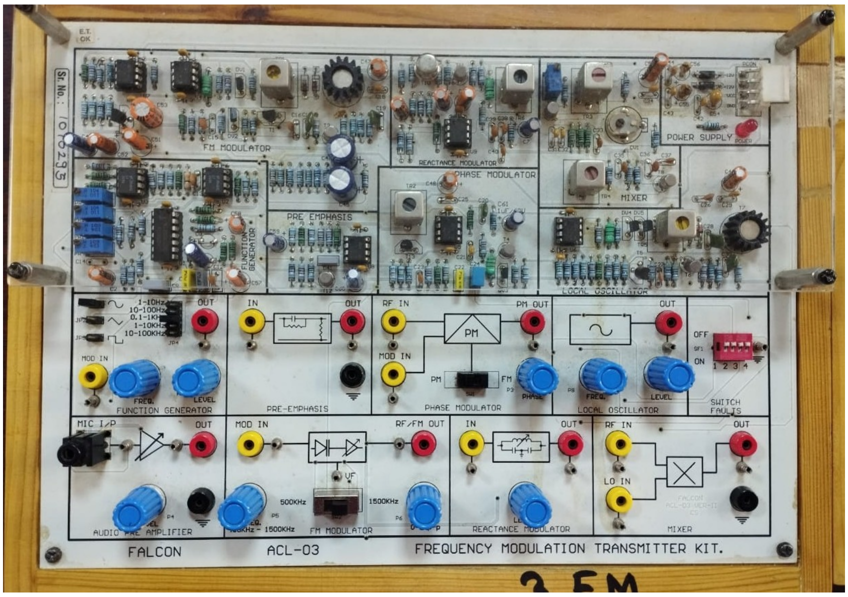


(c) Modulated signal

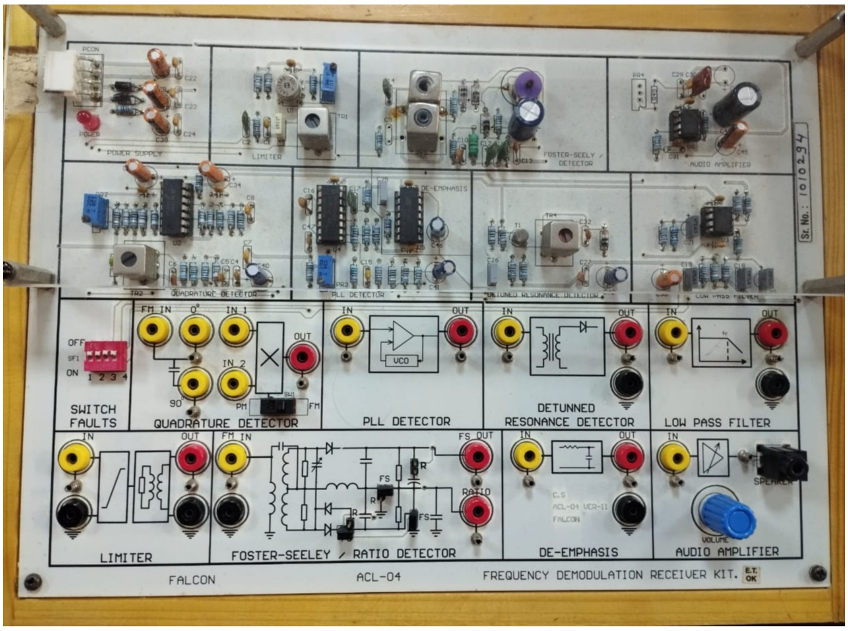
6 Experimental Setup



(a) Actual setup

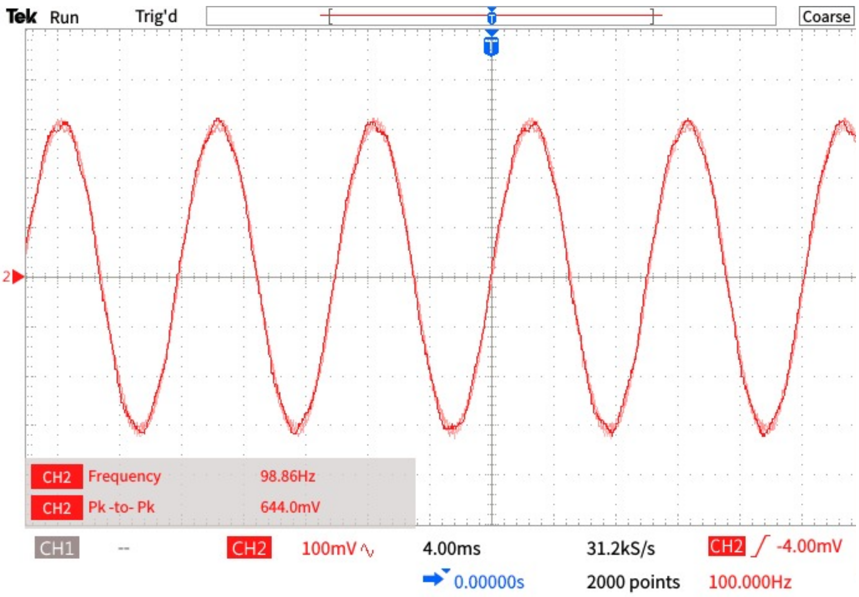


(b) Actual setup

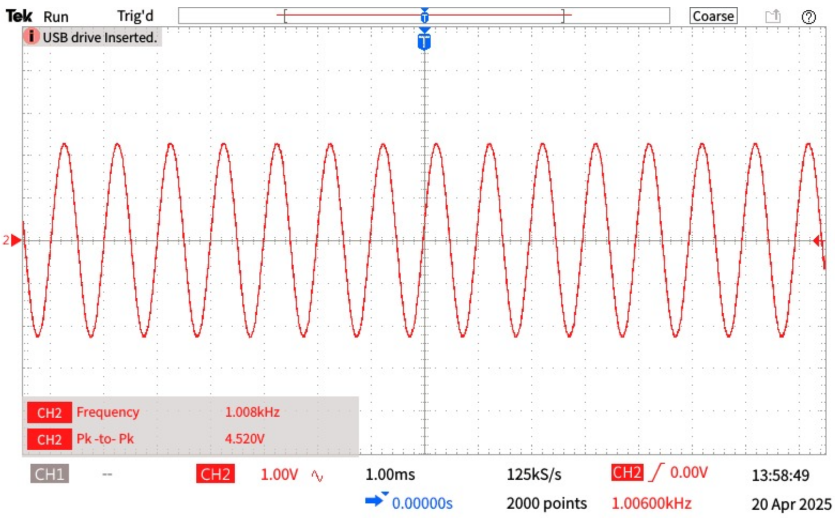


(c) Actual setup

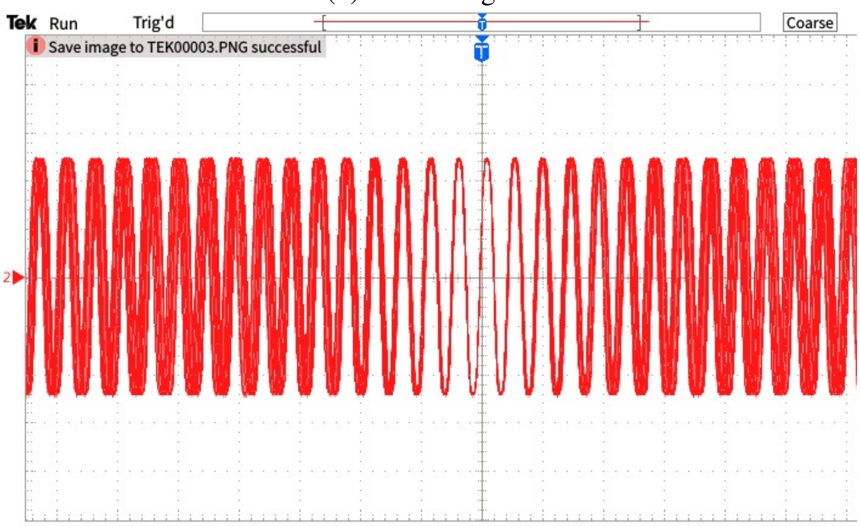
7 Experimental Wavehape



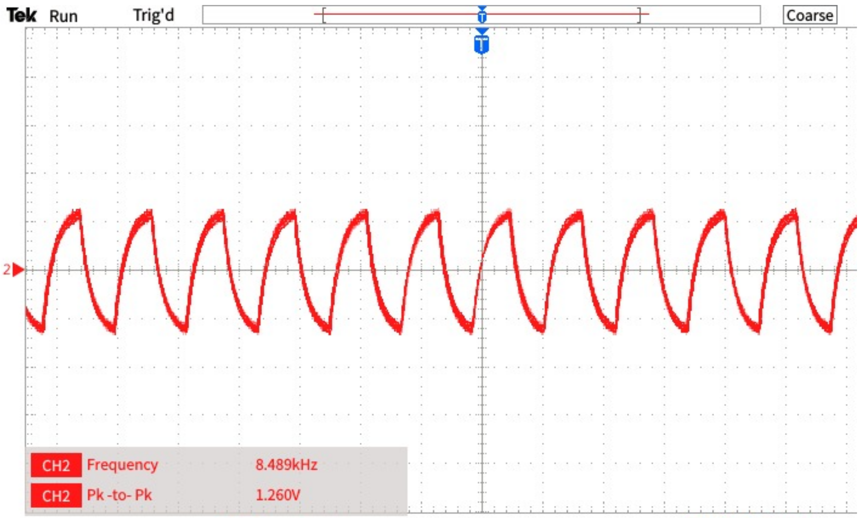
(a) Message Signal



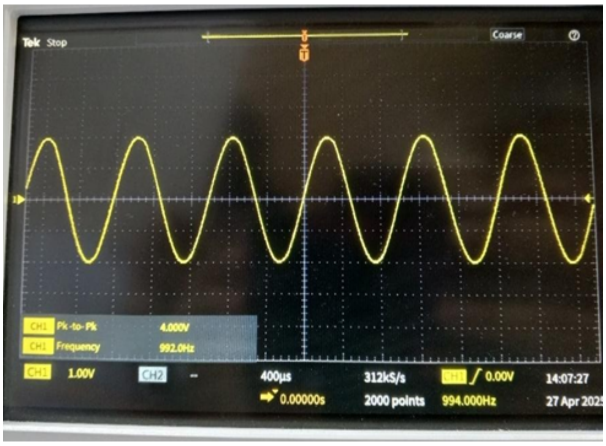
(b) Carrier Signal



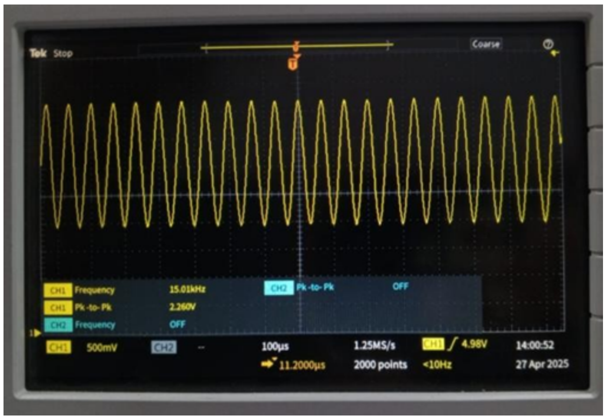
(c) Modulated signal



(a) Demodulated signal

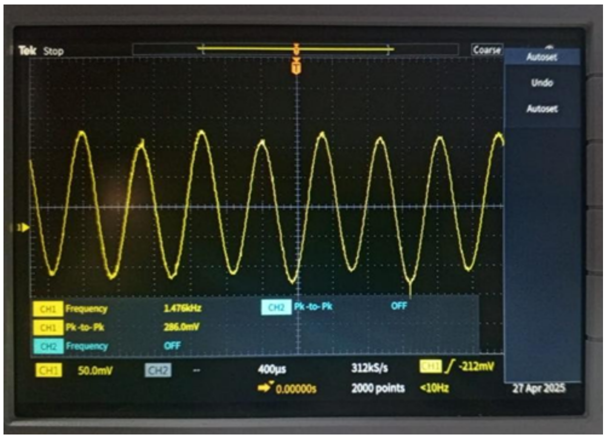


(a) Message signal Frequency 992 Hz , Peak to Peak Voltage 4V



(b) Carrier signal Frequency 15010 Hz, Peak to Peak Voltage 2.26 V

(c) Modulated Signal Frequency 16.15 kHz, Peak to Peak Voltage 4.72 V



(d) Demodulated Signal Frequency 1.476 kHz, Peak to Peak Voltage 286 mV

8 Discussion

In the experiment, frequency modulation and demodulation were observed using a frequency-modulation transmitter kit and a frequency-demodulation receiver kit. The transmitter circuit was assembled as per the provided manual, where both the message and carrier signals were generated using signal generators. These signals were used to produce a frequency modulated waveform by varying the instantaneous frequency of the carrier in accordance with the amplitude of the message signal. The modulated signal was then transmitted to the demodulation kit. The receiver employed a frequency discriminator circuit, which successfully recovered the original message signal from the modulated waveform, demonstrating the working principle of frequency modulation and demodulation.