Heaven's Light is Our Guide

Rajshahi University of Engineering and Technology

Course Code

ECE 3208

Course Title

Communication Engineering Sessional

Experiment Date: January 21, 2025,
Submission Date: February 11, 2025

Lab Report 3:
Determination of Modulation Index of FM Wave

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Contents

Determination of Modulation Index of FM Wave

Theory

Frequency Modulation (FM) encodes information by varying the instantaneous frequency of a carrier wave, making it more resistant to noise than Amplitude Modulation (AM).
The message signal:

$$m(t) = A_m \cos(2\pi f_m t)$$

The carrier signal:

$$c(t) = A_c \cos(2\pi f_c t)$$

The FM modulated signal:

$$s(t) = A_c \cos\left(2\pi f_c t + \beta \sin(2\pi f_m t)\right)$$

where $\beta = \frac{\Delta f}{f_m}$.
The demodulated signal:

$$V_0(t) = \frac{f_{\text{inst}}(t) - f_c}{\Delta f}$$

To determine Δf:

1. Observe the modulated signal on an oscilloscope.
2. Measure the maximum (f_{max}) and minimum (f_{min}) frequencies.
3. Calculate $\Delta f = \frac{f_{\text{max}} - f_{\text{min}}}{2}$.

The bandwidth (B) of an FM signal, according to Carson's rule:

$$B \approx 2(\Delta f + f_m) = 2f_m(\beta + 1)$$

FM is widely used in radio broadcasting and two-way radio communication due to its noise immunity and efficient bandwidth use [1, 2].

Required Apparatus

- ANALOGUE SIGNAL TRANSMISSION DL 3155M60
- Oscilloscope
- Connecting Wires
- Power Supply

Block Diagram

FM Modulation and Demodulation

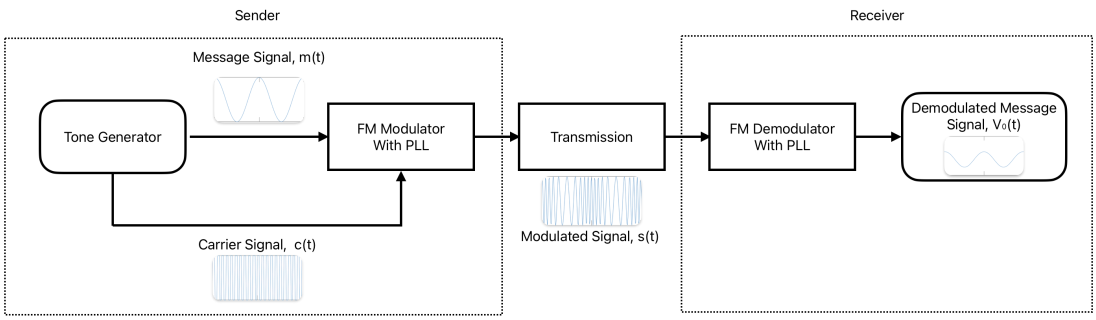

Figure 1: Block Diagram of FM Modulation and Demodulation

Procedure

1. The FM modulator and demodulator were connected as shown in the block diagram.
2. The message signal was applied to the modulator and the modulated signal was observed on the oscilloscope.
3. The frequency deviation and the modulating frequency were measured from the oscilloscope.
4. The modulation index was calculated using the measured values.
5. The experiment was repeated with different message signals and modulation frequencies to observe their effects.
6. The observed values of frequency deviation, modulating frequency, and modulation index for each experiment were recorded.

Experimental Data

Reading no	Message Signal's		Modulated Signal's Minimum		Modulated Signal's Maximum	
	Time Period, (s)	Frequency, (kHz)	Time Period, (s)	Frequency, (kHz)	Time Period, (s)	Frequency, (kHz)
1	1.4×10^{-4}	7.142	1.1×10^{-5}	90.90	3×10^{-5}	33.33
2	1.4×10^{-4}	7.142	1.05×10^{-5}	95.24	3.3×10^{-5}	30.3
3	9×10^{-5}	11.11	1.2×10^{-5}	83.33	2.5×10^{-5}	40
4	2.4×10^{-4}	3.937	1.1×10^{-5}	90.91	2.4×10^{-5}	41.67

Calculations

The modulation index (β) is calculated using the formula:

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

where Δf is the frequency deviation and f_m is the frequency of the message signal. The bandwidth (B) of an FM signal can be calculated using Carson's rule:

$$B \approx 2(\Delta f + f_m) = 2f_m(\beta + 1)$$

1. For Reading 1:

$$f_m = 7.142 \text{ kHz}$$
$$\Delta f = \frac{90.90 - 33.33}{2} \text{ kHz} = 28.785 \text{ kHz}$$
$$\beta = \frac{28.785}{7.142} \approx 4.03$$
$$B \approx 2 \times 7.142 \text{ kHz} \times (4.03 + 1) \approx 71.42 \text{ kHz}$$

2. For Reading 2:

$$f_m = 7.142 \text{ kHz}$$
$$\Delta f = \frac{95.24 - 30.3}{2} \text{ kHz} = 32.47 \text{ kHz}$$
$$\beta = \frac{32.47}{7.142} \approx 4.55$$
$$B \approx 2 \times 7.142 \text{ kHz} \times (4.55 + 1) \approx 81.42 \text{ kHz}$$

3. For Reading 3:

$$f_m = 11.11 \text{ kHz}$$
$$\Delta f = \frac{83.33 - 40}{2} \text{ kHz} = 21.665 \text{ kHz}$$
$$\beta = \frac{21.665}{11.11} \approx 1.95$$
$$B \approx 2 \times 11.11 \text{ kHz} \times (1.95 + 1) \approx 67.11 \text{ kHz}$$

4. For Reading 4:

$$f_m = 3.937 \text{ kHz}$$
$$\Delta f = \frac{90.91 - 41.67}{2} \text{ kHz} = 24.62 \text{ kHz}$$
$$\beta = \frac{24.62}{3.937} \approx 6.25$$
$$B \approx 2 \times 3.937 \text{ kHz} \times (6.25 + 1) \approx 63.50 \text{ kHz}$$

Results

The modulation index (β) and bandwidth (B) for each reading are summarized as follows:

- For Reading 1:
  - Modulation Index: $\beta \approx 4.03$
  - Bandwidth: $B \approx 71.42$ kHz
- For Reading 2:
  - Modulation Index: $\beta \approx 4.55$
  - Bandwidth: $B \approx 81.42$ kHz
- For Reading 3:
  - Modulation Index: $\beta \approx 1.95$
  - Bandwidth: $B \approx 67.11$ kHz
- For Reading 4:
  - Modulation Index: $\beta \approx 6.25$
  - Bandwidth: $B \approx 63.50$ kHz

Matlab Simulation

Code:

```
% Parameters
fs = 1000;          % Sampling frequency
t = 0:1/fs:1;       % Time vector
fc = 100;           % Carrier frequency
kf = 50;            % Frequency sensitivity
Am = 1;             % Amplitude of message signal
fm = 10;            % Frequency of message signal
```

```
% Message signal
m = Am * cos(2 * pi * fm * t);

% Carrier signal (square wave)
c = square(2 * pi * fc * t);

% FM Modulation
int_m = cumsum(m) / fs;  % Integral of message signal
s = cos(2 * pi * fc * t + 2 * pi * kf * int_m);

% FM Demodulation
y = diff([0 s]) * fs;    % Differentiate the FM signal
y = abs(hilbert(y));     % Envelope detection

% Modulation Index
beta = kf * Am / fm;
disp(['Modulation Index (beta): ', num2str(beta)]);

% Plotting
figure;

subplot(4,1,1);
plot(t, m);
title('Message Signal');
xlabel('Time (s)');
ylabel('Amplitude');

subplot(4,1,2);
plot(t, c);
title('Carrier Signal (Square Wave)');
xlabel('Time (s)');
ylabel('Amplitude');

subplot(4,1,3);
plot(t, s);
title('FM Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');

subplot(4,1,4);
plot(t, y(1:length(t)));
title('Demodulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
```

```
% Zoomed-in view of FM Modulated Signal to show frequency variations
zoom_factor = 10;  % Factor to zoom in
zoom_t = t(1:fs/zoom_factor);  % Zoomed-in time vector
zoom_s = s(1:fs/zoom_factor);  % Zoomed-in FM signal

figure;
plot(zoom_t, zoom_s);
title('Zoomed-in FM Modulated Signal');
xlabel('Time (s)');
ylabel('Amplitude');
```

Output

Experimental Output

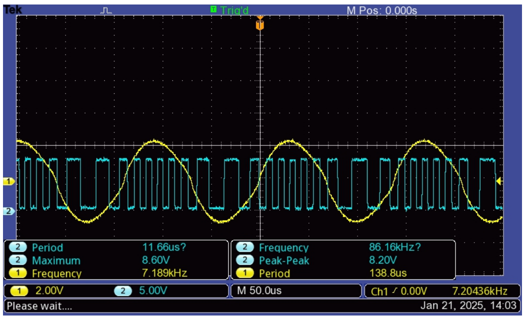

Figure 2: FM; Yellow: Message, Blue: Modulated Signal 1

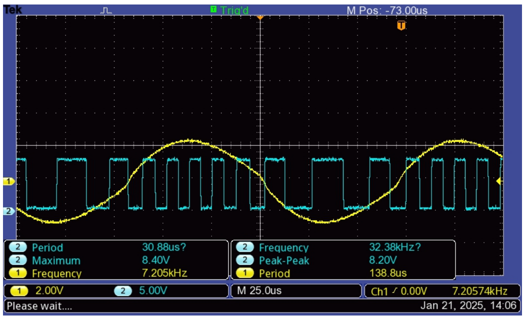

Figure 3: FM; Yellow: Message, Blue: Modulated Signal 2

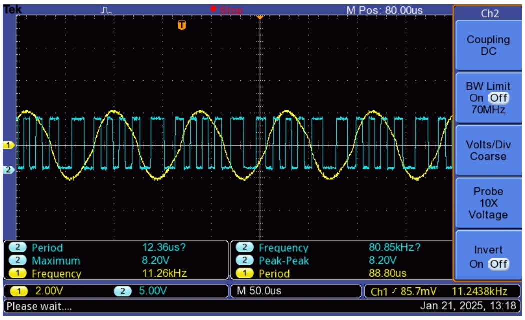

Figure 4: FM; Yellow: Message, Blue: Modulated Signal 3

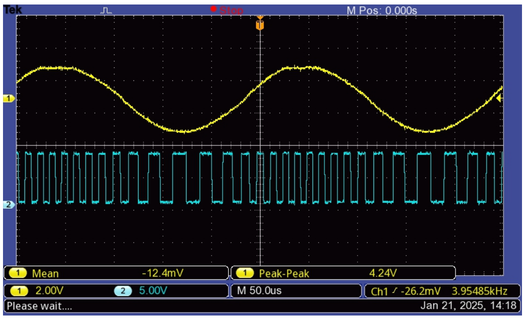

Figure 5: FM; Yellow: Message, Blue: Modulated Signal 4

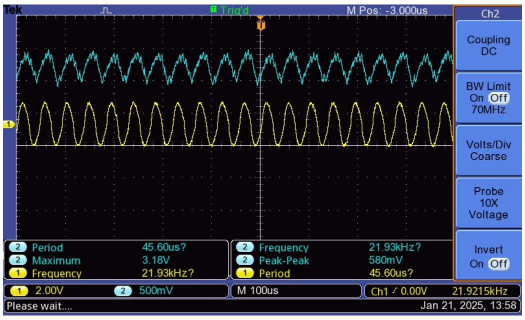

Figure 6: Demodulated; Yellow: Message, Blue: Demodulated Signal 1

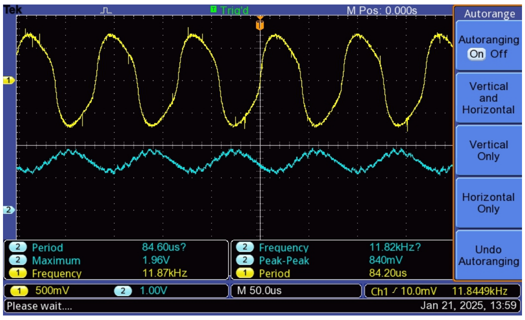

Figure 7: Demodulated; Yellow: Message, Blue: Demodulated Signal 2

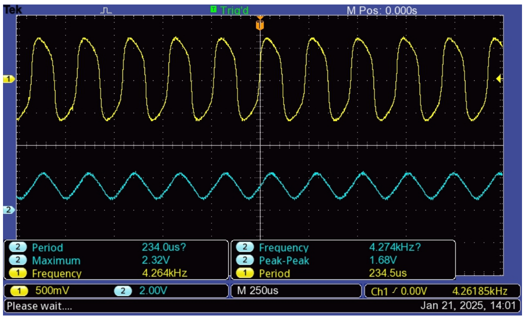

Figure 8: Demodulated; Yellow: Message, Blue: Demodulated Signal 3

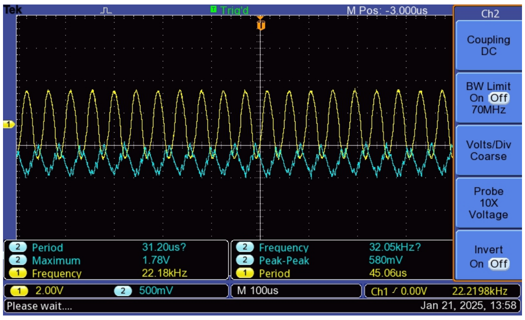

Figure 9: Demodulated; Yellow: Message, Blue: Demodulated Signal 4

Matlab Simulation Output

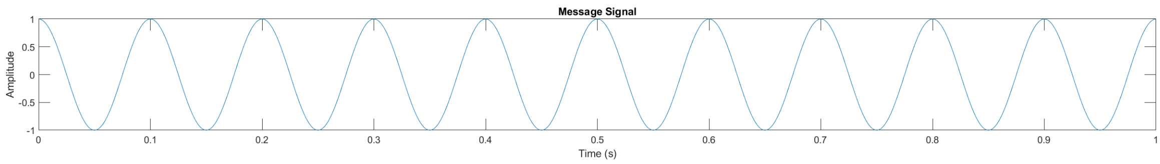

Figure 10: Message Signal

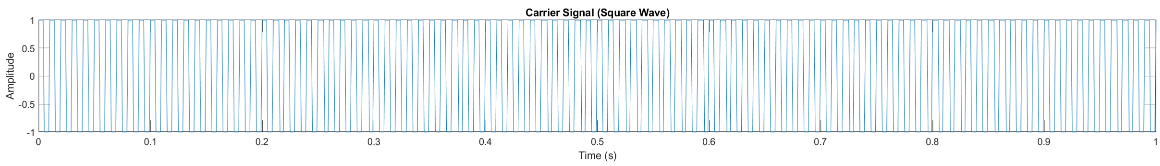

Figure 11: Carrier Signal, Square Wave

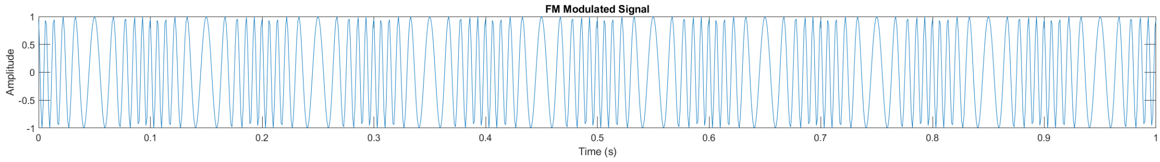

Figure 12: FM Modulated Signal

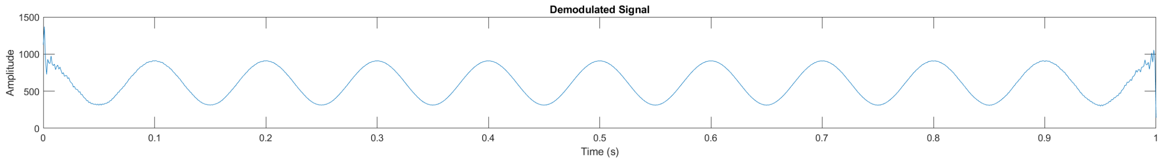

Figure 13: Demodulated Signal

Discussion and Conclusion

The modulation index (β) was found to be crucial in Frequency Modulation (FM) as it determined the bandwidth and the number of significant sidebands. In this experiment, β was calculated for different message signals and modulation frequencies using $\beta = \frac{\Delta f}{f_m}$. Significant variations in β (1.95 to 6.25) were observed, impacting the bandwidth and quality of FM signals. The Matlab simulations confirmed the relationship between β and bandwidth, highlighting the importance of selecting an appropriate β for efficient communication. Valuable insights into the effects of β on FM signals and its significance in FM modulation were provided by this experiment.

Matlab simulations confirmed the relationship between β and bandwidth, highlighting the importance of selecting an appropriate β for efficient communication. Valuable insights into the effects of β on FM signals and its significance in FM modulation were provided by this experiment. The results obtained from the experiment and Matlab simulations were consistent, demonstrating the accuracy and reliability of the calculations. Overall, the experiment was successful in determining the modulation index of FM waves and understanding its impact on signal quality and bandwidth.

References

[1] S. Haykin, *Communication Systems.* Wiley, 2008.

[2] J. G. Proakis and M. Salehi, *Digital Communications.* McGraw-Hill, 2007.