Aim ↬ To study the concept and fundamentals of Frequency Modulation and Demodulation.

Software Required ↬ MATLAB

Theory ↬

Frequency Modulation (FM) is a modulation technique in which the frequency of a carrier signal is varied in proportion to the instantaneous amplitude of the message or baseband signal. This method allows for better noise immunity and signal integrity over long distances compared to Amplitude Modulation. The carrier signal is typically a high-frequency sinusoidal wave, and the modulation creates a frequency spectrum that occupies more bandwidth than AM.

In FM, the modulated signal s(t) can be expressed as:

$$s(t) = A_c \cdot \cos\left(2\pi f_c t + \frac{A_m}{f_m} \cdot m(t)\right)$$

The modulation index μ is defined as the ratio of the frequency deviation to the frequency of the modulating signal:

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

where Δf is the maximum frequency deviation. A higher modulation index results in greater frequency deviation and a wider bandwidth.

Generation of FM Signal ↴

FM signals can be generated using direct frequency modulation techniques or through phase modulation. In direct frequency modulation, the instantaneous frequency of the carrier signal is varied based on the message signal. The bandwidth of an FM signal can be estimated using Carson's Rule:

$$B_T = 2(f_m + \Delta f)$$

where f_m is the highest frequency in the message signal.

Demodulation of FM Signal ↴

FM demodulation can be accomplished through several methods, including frequency discriminator techniques and phase-locked loops. One common method is the use of a phase-locked loop (PLL), which extracts the original message signal by comparing the phase of the received FM signal with the phase of a locally generated carrier. The output provides a signal proportional to the message, which can be filtered to remove noise.

Frequency Spectrum of FM Signal ↴

The frequency spectrum of an FM signal exhibits a carrier frequency fcf_cfc and sidebands at frequencies fc+nfmf_c + n f_mfc+nfm and fc−nfmf_c - n f_mfc−nfm, where nnn is an integer representing the sideband order. The total power of an FM signal is concentrated in the sidebands, allowing for efficient transmission without the need for a significant carrier component.

Applications of FM ↴

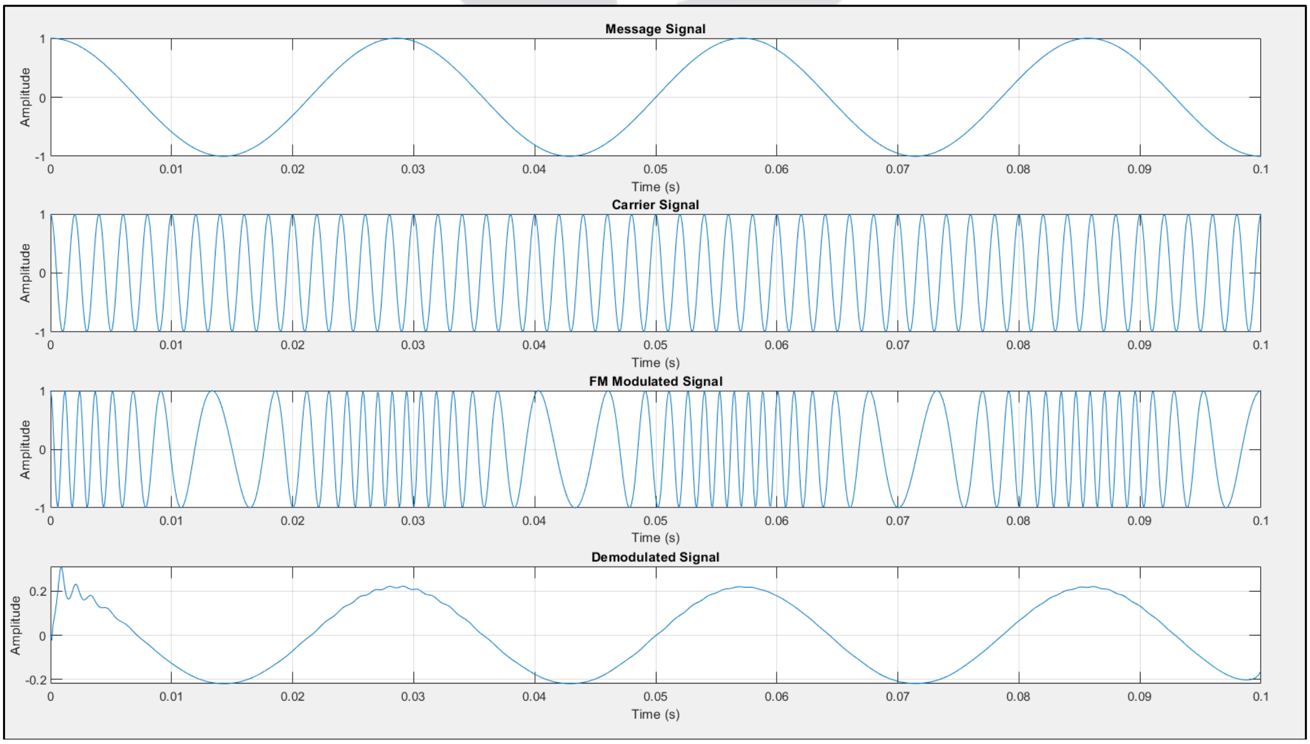
FM is extensively used in radio broadcasting (FM radio), television audio, and two-way radio communication due to its resistance to noise and interference. It is also employed in data communication systems and is often preferred in high-fidelity audio transmission.

Code ↬

```
% Frequency Modulation
clc;
clear;
close all;

Ac = 1;
Am = 1;
Fm = 35;
Fc = 500;
fs = 10000;
t = (0:0.1*fs)/fs;

mt = Am * cos(2 * pi * Fm * t);
carrier_signal = Ac * cos(2 * pi * Fc * t);
fm_signal = Ac * cos(2 * pi * Fc * t + 10 * sin(2 * pi * Fm * t));

d = demod(fm_signal, Fc, fs, 'fm');

figure;
subplot(4,1,1);
plot(t, mt);
xlabel('Time (s)');
ylabel('Amplitude');
title('Message Signal');
grid on;
```

```
subplot(4,1,2);
plot(t, carrier_signal);
xlabel('Time (s)');
ylabel('Amplitude');
title('Carrier Signal');
grid on;

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

subplot(4,1,4);
plot(t, d);
xlabel('Time (s)');
ylabel('Amplitude');
title('Demodulated Signal');
grid on;
```

Output ↬



Result ↬

The experiment illustrated the behavior of Frequency Modulated (FM) signals. The modulating and carrier signals appeared as sinusoidal waveforms, with the FM signal exhibiting frequency variations in response to the modulating signal. The demodulated output successfully recovered the original message, demonstrating FM's ability to maintain signal integrity and resistance to noise.

Conclusion ↬

The experiment shows that Frequency Modulation effectively transmits information with improved noise immunity and signal integrity compared to other modulation methods. The generation and demodulation techniques provide reliable communication over various distances.

Precautions ↬

- Ensure the carrier amplitude is properly chosen to avoid overmodulation and signal distortion.
- Maintain appropriate sampling rates to avoid aliasing during signal generation and analysis.
- Use proper filtering techniques to minimize noise in the demodulated signal.