Date 9/09/2020

Expt. No. 4 Adm No: U19CS048 Page Nos: 49-65

Experiment No: 04

FREQUENCY MODULATION AND DEMODULATION

Objective: To demonstrate frequency modulation (FM) and demodulation process by observing the waveforms in time domain and their spectra in frequency domain by varying the parameters of message signal. Draw waveforms and Spectra. Use virtual mode with appropriate Software.

Apparatus: Software used:
1) MATLAB 2) Labalive (FM)

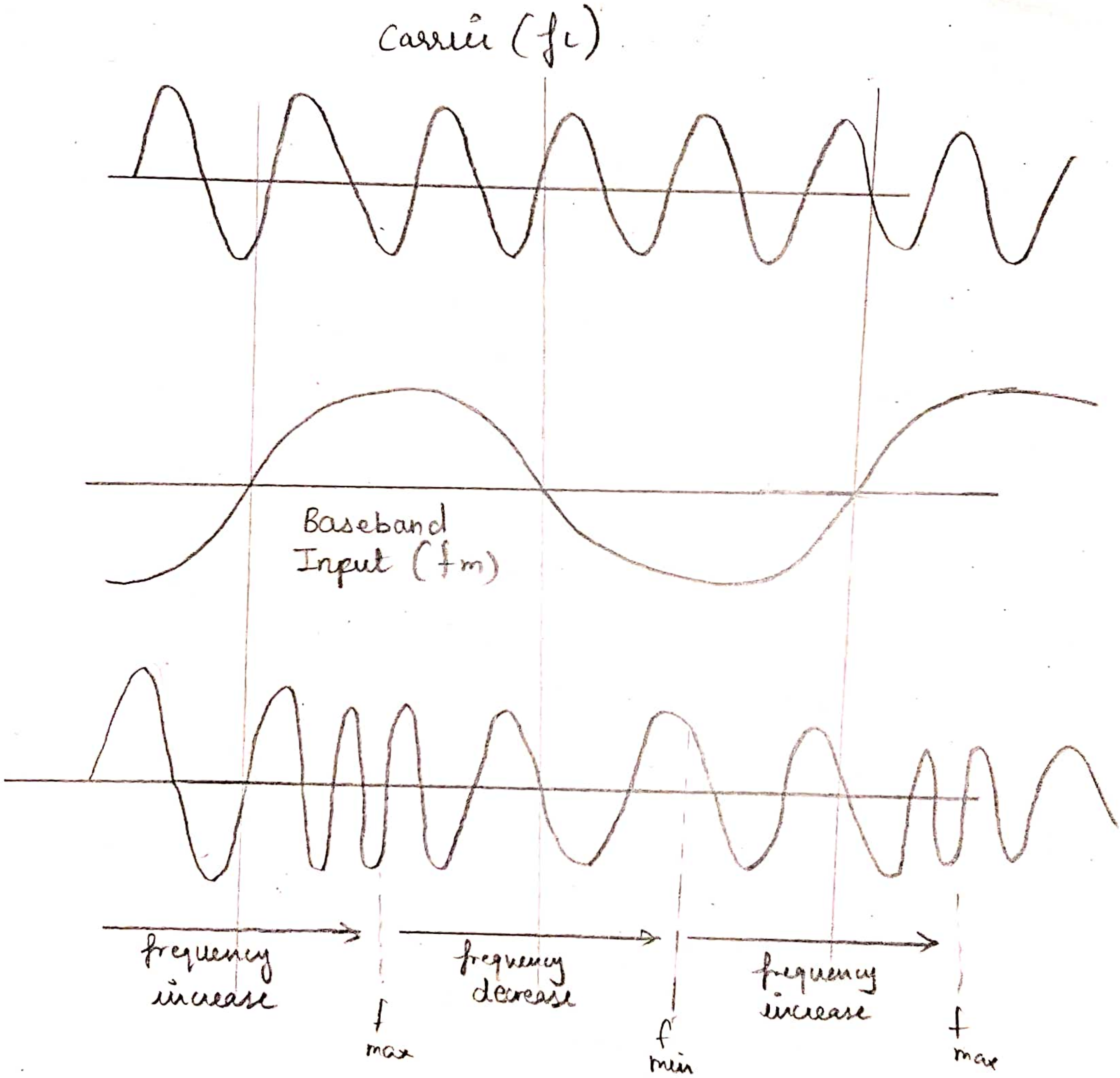
Theory:

Theoritical Background →

Amplitude modulation was the first modulation type to be considered in analog communication systems. Although it had obvious advantage of being simple and relatively bandwidth efficient it has some disadvantages too:

→ Since the message is embedded in the amplitude of the carrier signal, the cost, performance, and the size of the linear amplifiers are difficult to accomplish for obtaining fair performance in AM systems

→ When the message goes through a quiet period in Double Side Band (DSB) or Single Side Band (SSB) systems, very small carrier signals are transmitted. The absence of the signal tends to accentuate the noise


Carrier (fc)
Baseband
Input (fm)
frequency
increase
f
max
frequency
decrease
f
min
frequency
increase
f
max

→ The passband bandwidth is small compared to the other modulation schemes i.e FM cellular, Wi-Fi etc.

A major improvement in performance in the transmission is achieved with angle modulation. In this type of modulation the amplitude of the carrier is kept constant. Angle modulation provides improvised noise performance. Frequency modulation technique is analyzed under angle modulation.

FREQUENCY MODULATION: It is the process of varying the frequency of the carrier signal linearly with the message signal.

- The FM-modulated signal has its instantaneous frequency that varies linearly with the amplitude of the message signal. Now, we can get the FM-modulation by the following:

$$\Phi(t) = \cos\left(2\pi f_c t + 2\pi K_f \int^{t} m(t)\, dt\right)$$

Where K_f is the sensitivity factor, and represents the frequency deviation rate as a result of message amplitude change. The instantaneous frequency is →

$$W_i = 2\pi f_c + 2\pi K_f m(t)$$

MODULATION INDEX: The amount of change in the carrier frequency produced by the amplitude of the input modulating signal, is called frequency deviation.

Modulating signal: $m(t) = E_m \cos(2\pi f_m t)$

Carrier signal: $E_c \sin(2\pi f_c t)$

Freq. of FM signal :-

$$F(t) = f_c + K_f\, m(t)$$
$$= f_c + K_f E_m \cos(2\pi f_m t)$$
$$\Delta f = K_f E_m$$
$$F(t) = f_c + \Delta f \cos(2\pi f_m t)$$

$\Delta f = K_f E_m$, frequency deviation

Max. frequency deviation $\Rightarrow$ $f_c \pm \Delta f$

<u>FM Signal</u> :

$$y_{FM}(t) = E_c \sin\left(w_c t + K_f 2\pi \int_0^t m(t)\, dt\right)$$
$$= E_c \sin\left(w_c t + K_f 2\pi \int_0^t E_m \cos(2\pi f_m t)\, dt\right)$$
$$= E_c \sin\left(w_c t + \frac{K_f (2\pi) E_m}{(2\pi) f_m} \sin(2\pi f_m t)\right)$$
$$= E_c \sin\left(w_c t + \frac{K_f E_m}{f_m} \sin(2\pi f_m t)\right)$$
$$= E_c \sin\left(w_c t + \frac{\Delta f}{f_m} \sin(2\pi f_m t)\right)$$

Modulation Index of FM $= \dfrac{\Delta f}{f_m}$

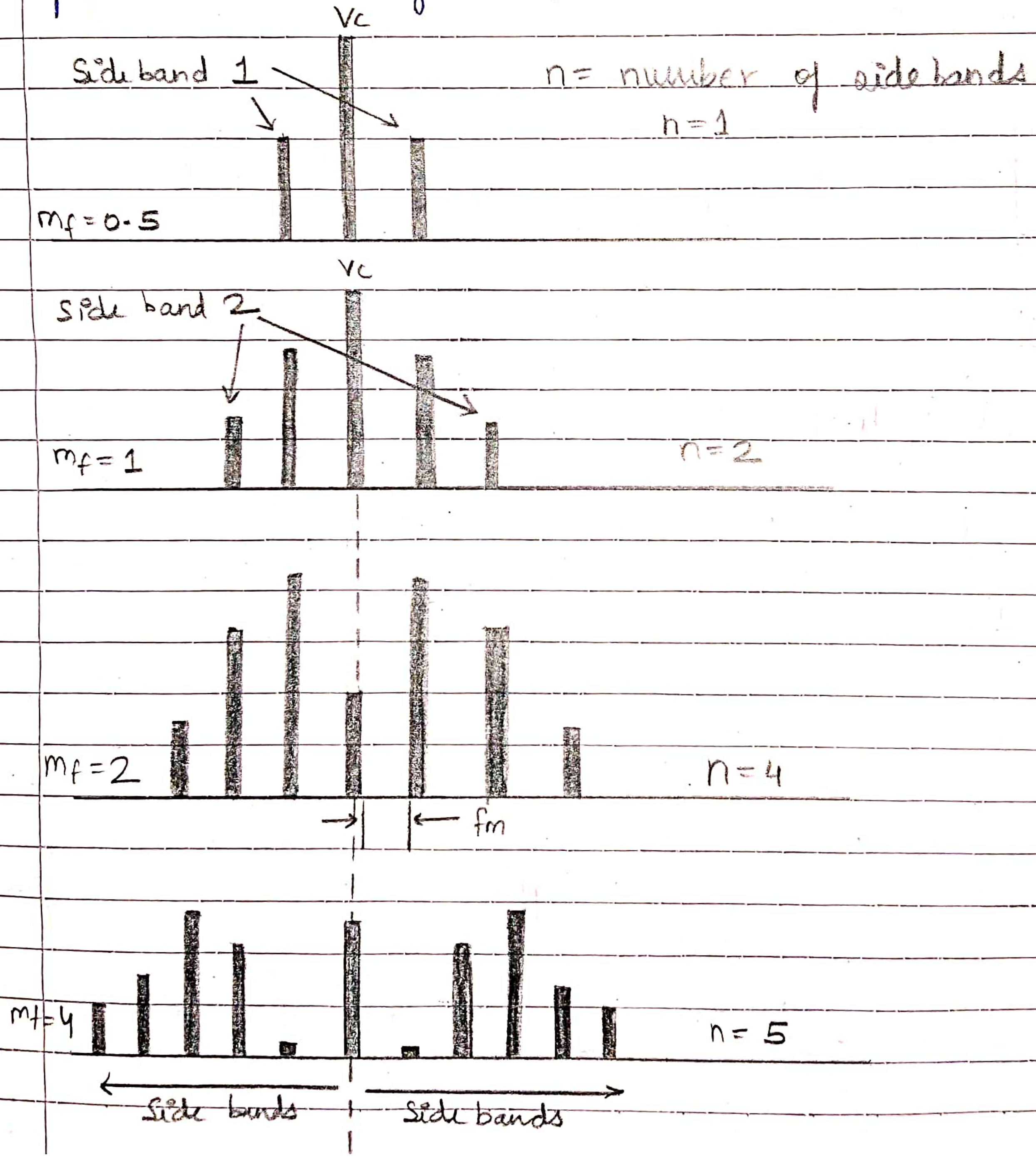
$$\boxed{m_f = \frac{\Delta f}{f_m}}$$

Frequency modulation Equation $\Rightarrow$

$$y_{FM}(t) = E_c \sin(w_c t + m_f \sin(2\pi f_m t))$$

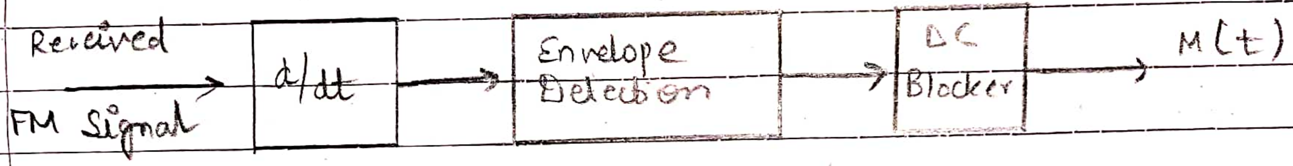
Bandwidth ⇒

FM signal spectrum is quite complex and will have infinite number of sidebands as shown in figure. This figure gives idea, how the spectrum expands as the modulation index increases. Sidebands are seperated from the carrier by $f_c \pm f_m$, $f_c \pm 2f_m$, $f_c \pm 3f_m$ and so on.



FM Demodulation: It is the key process in the reception of a frequency modulated signal. Once the signal has been received, filtered and amplified, it is necessary to recover the original modulation from the carrier. It is this process that is called demodulation or detection.

Demodulation using Differentiation →
A frequency discriminator theoretically extracts the message from the received FM signal.



Difference between AM and FM:

→ In FM, carrier amplitude is constant, therefore transmitted power is constant

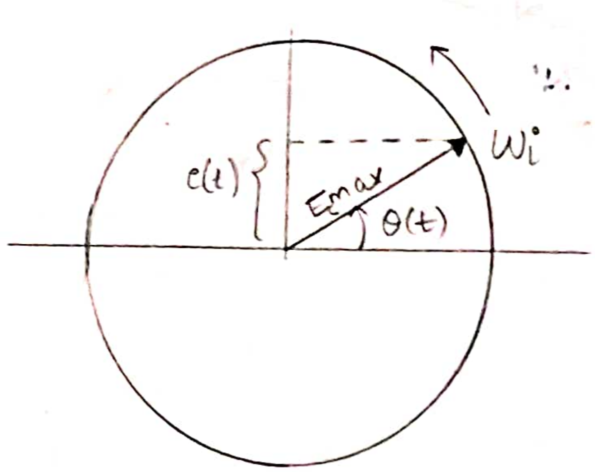
→ Transmitted power does not depend on the modulation index

→ The number of significant sidebands in FM is large

→ FM has better noise immunity. FM is rugged/robust against noise. The quality of FM will be good even in the presence of noise

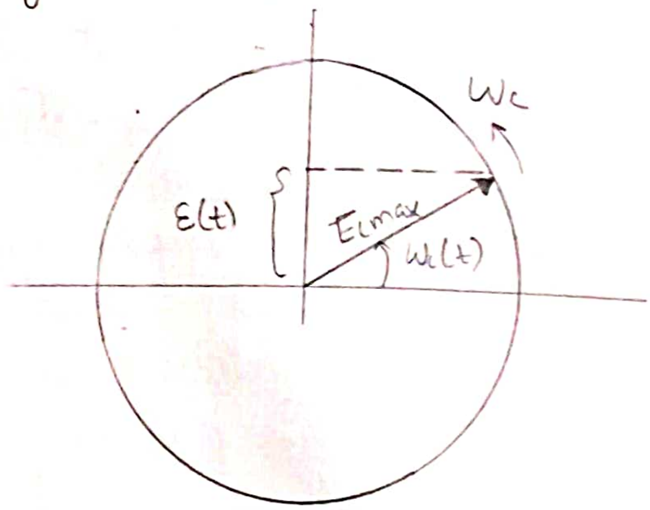
→ Circuits for FM transmitter are very complex and very expensive.

Rotating Phasor Representation of Carrier amplitude E_{cmax}:



(a)

Instantaneous angular Velocity $W_i(t)$

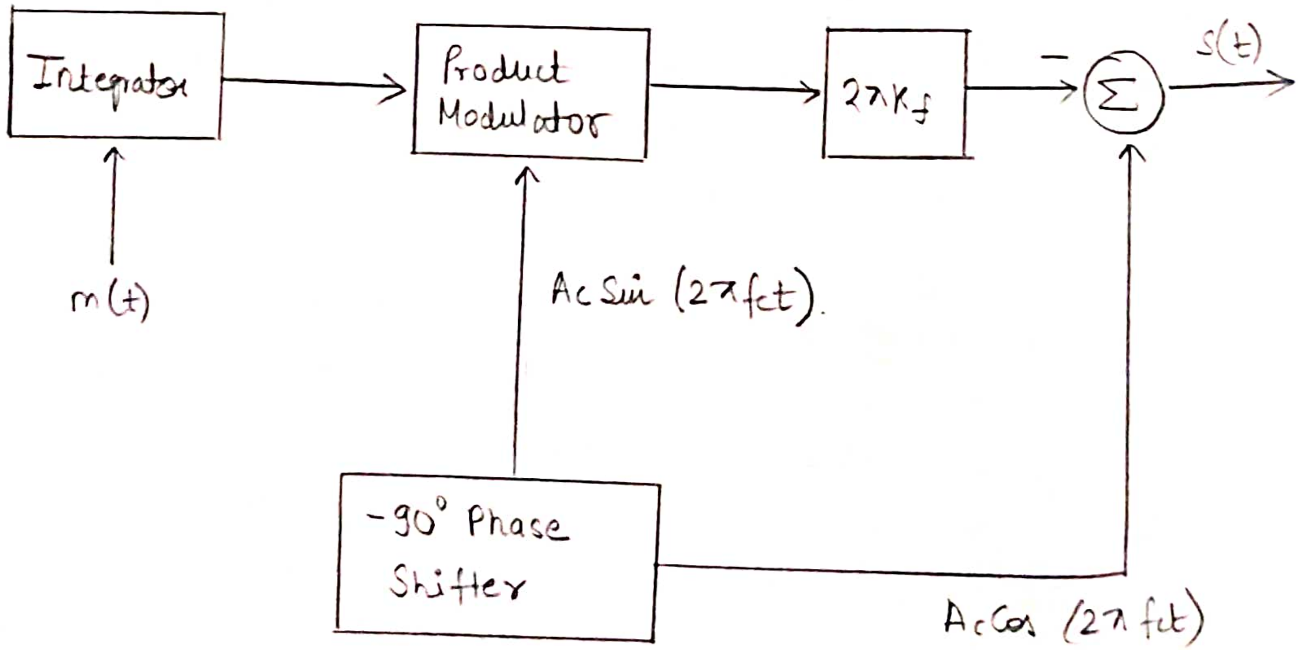


(b)

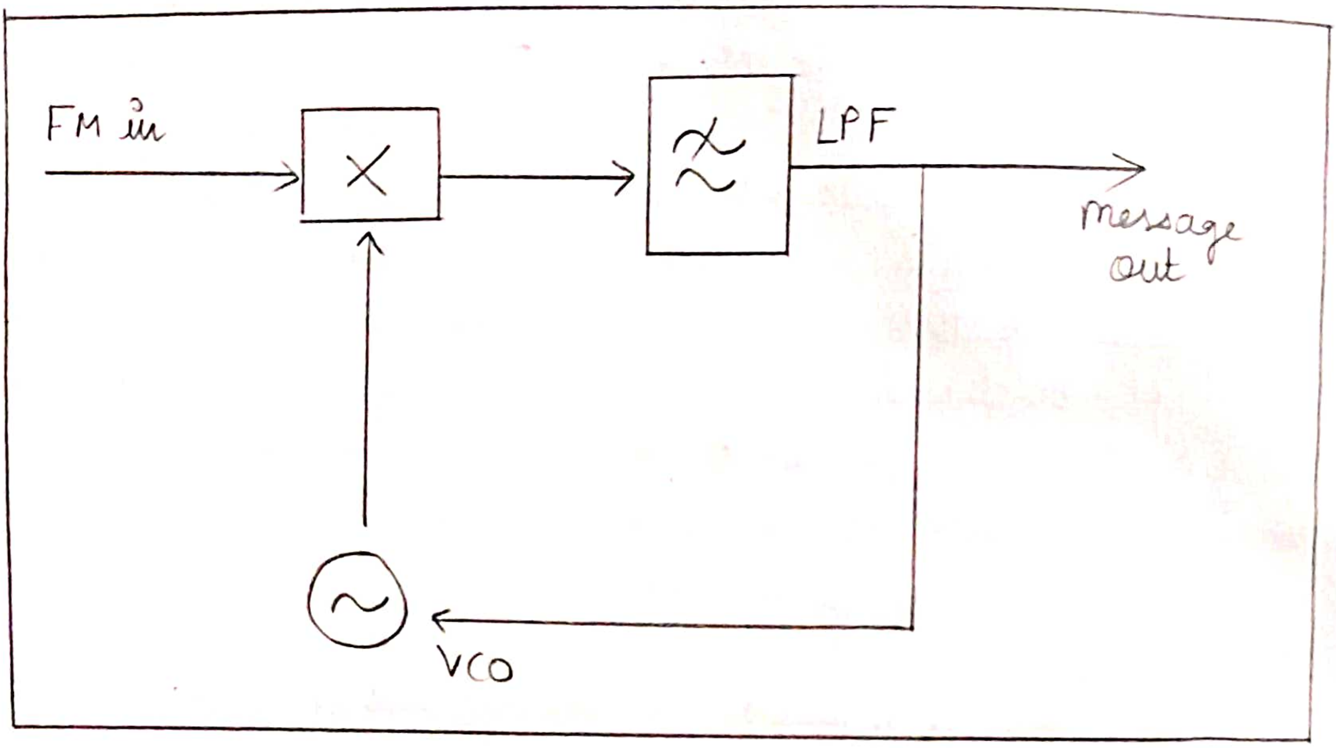
At constant Angular Velocity (W_c)

BLOCK DIAGRAM

FM Modulator:



FM Demodulator



Date ....

Expt. No. 4 Page No. 57

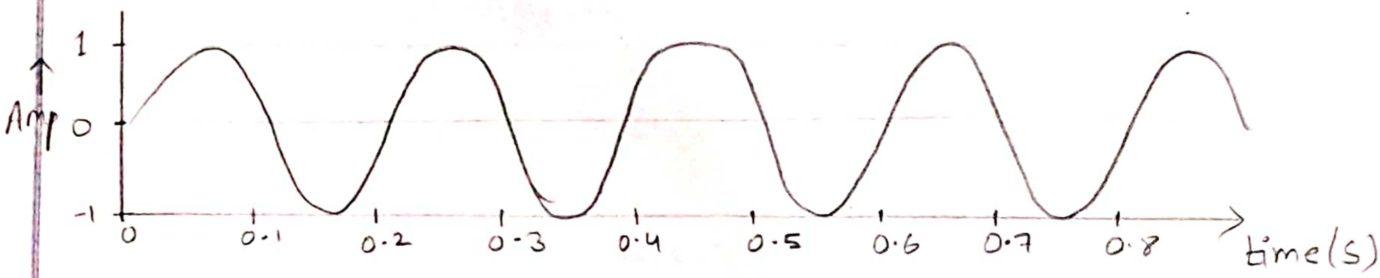
Matlab Code:

```
% Plot the frequency modulated signal
fc=30;
fm = 5;
ts = 1/(10*fc);
fs = (1/ts);
fdev = 10;      % Frequency deviation
t=0:ts:1;
m= sin (2* pi * fm*t);
c = cos (2*pi * fc*t);
%y = cos(wc * t +(kf *2* pi* cumsum (m)).* ts);
y= fmmod (m, fc, fs, fdev);
figure;
subplot (5,1,1)
plot (t,m)
title( 'Input Signal');
xlabel ('Time -->');
ylabel ('Amplitude');
subplot (5,1,2)
plot (t,c)
title ('Carrier signal');
Xlabel ('Time');
ylabel ('Amplitude');
Subplot (5,1,3)
plot (t,y)
title ('FM Modulation of input signal');
```

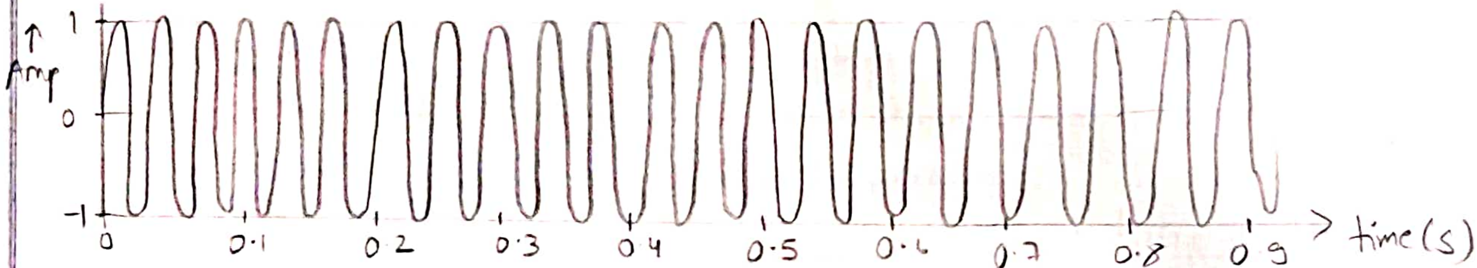
```
xlabel('Time');
ylabel('Amplitude');

% Demodulation
z=fmdemod(y,fc,fs,fdev);
subplot(5,1,4)
plot(t,z)
title('Demodulated FM Signal');

% Plot frequency spectra
a= fftshift(fft(y))*ts;
deltaf= fs/length(a);
f= -fs/2 : delta : fs/2-delta;
subplot(5,1,5)
plot(f, abs(a))
title('Magnitude Spectrum of FM Signal');
```

Matlab Observation:

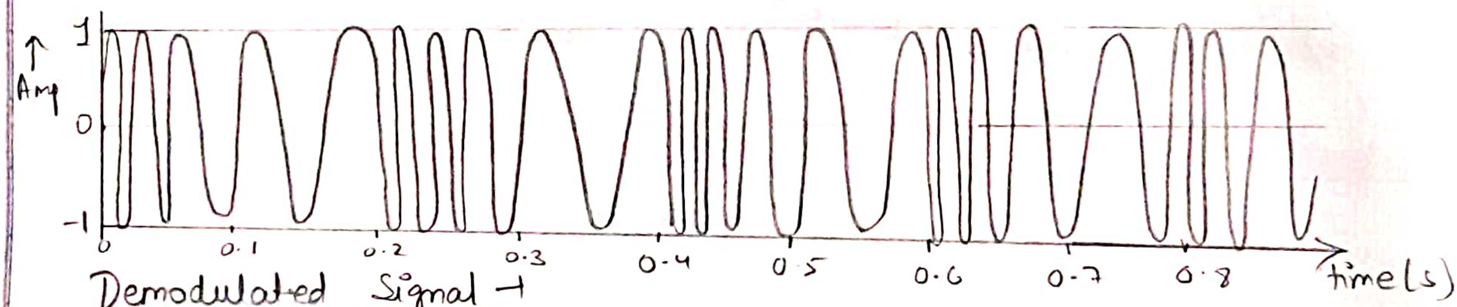
Input Signal →



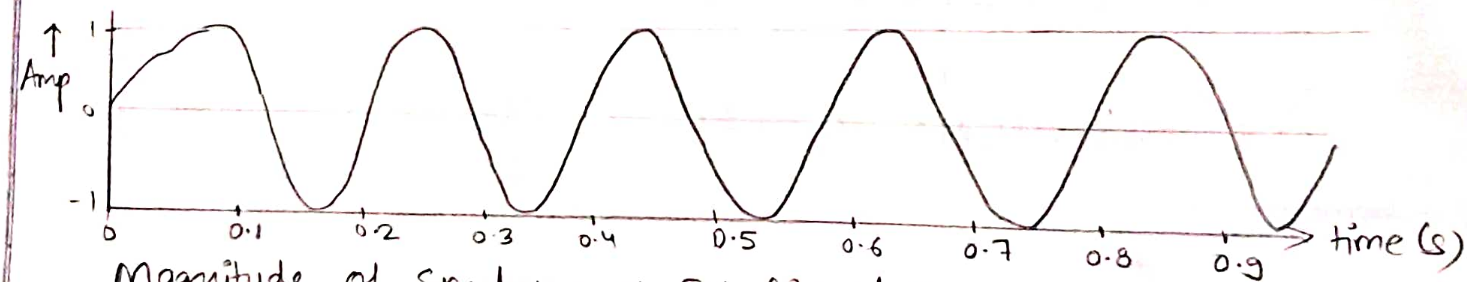
Carrier Signal →



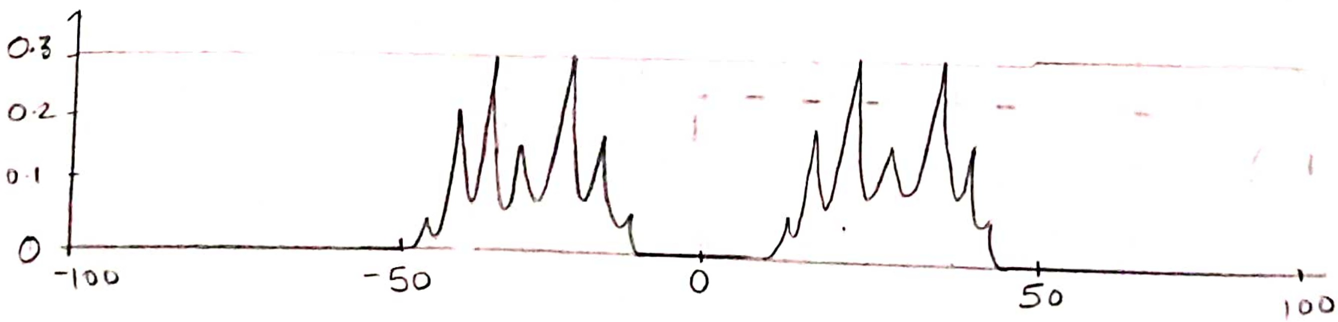
FM Modulated Signal →



Demodulated Signal →



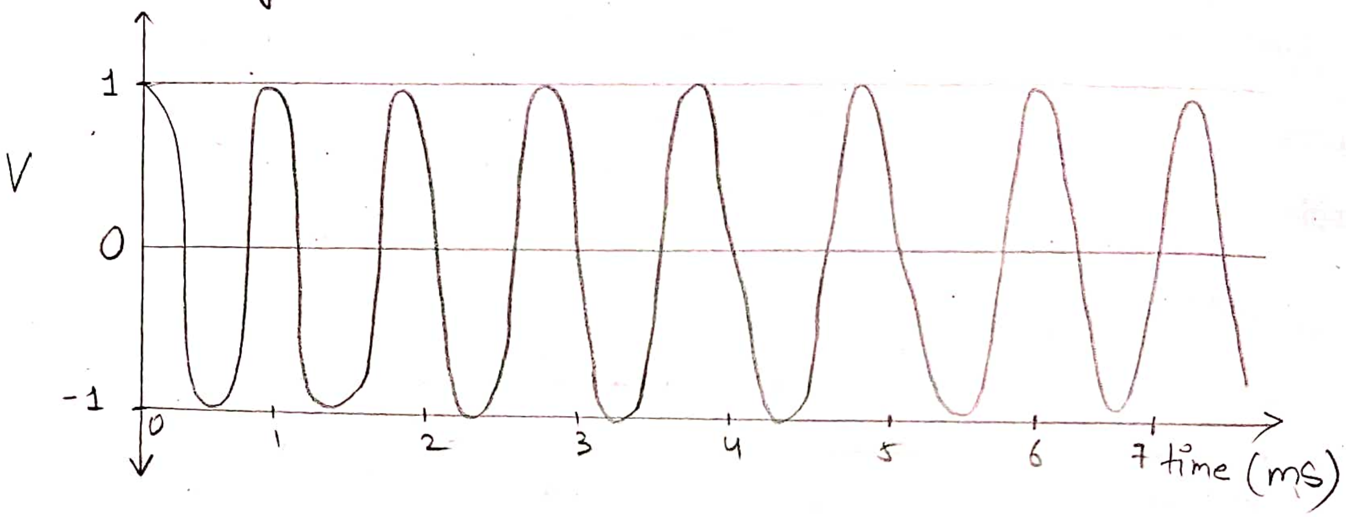
Magnitude of Spectrum of FM Signal →



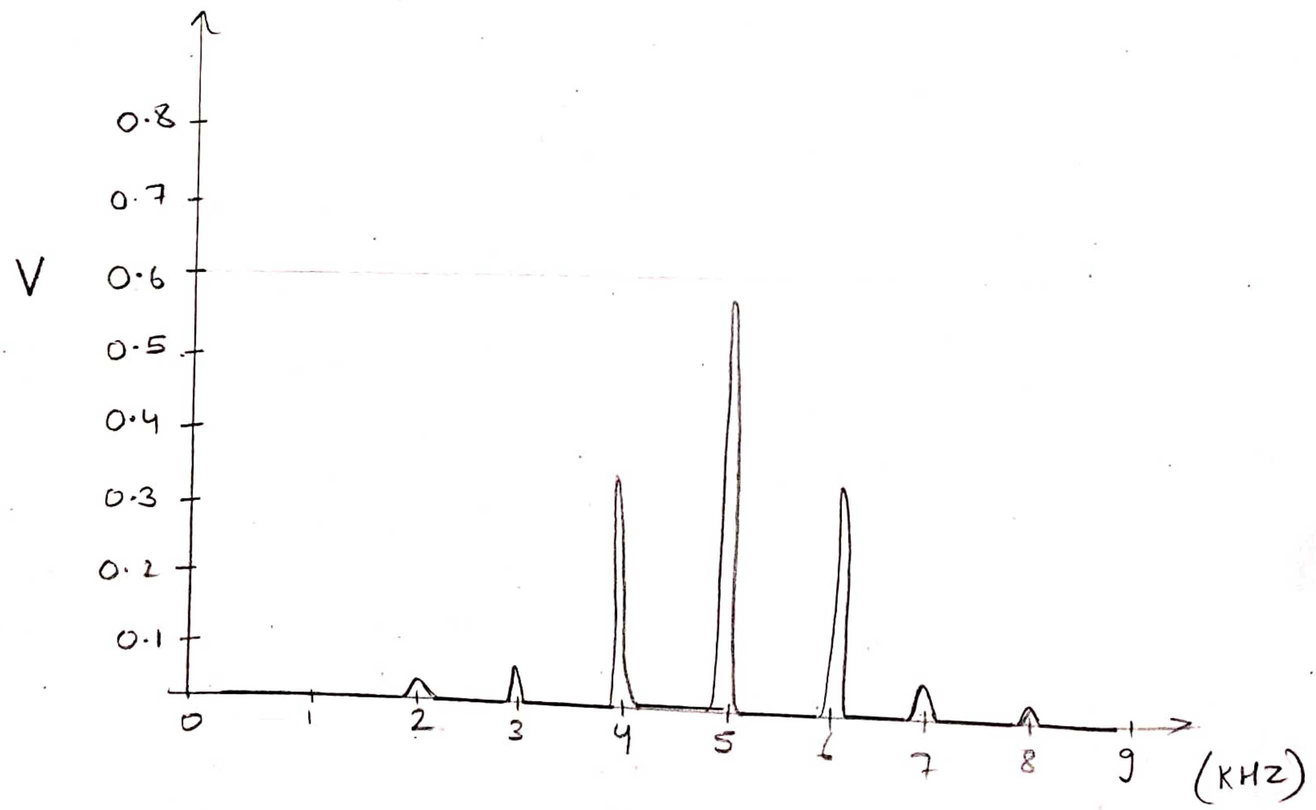
LABALIVE OBSERVATIONS:

1) Carrier: $f_c = 5KHZ$ $A_c = 1V$
Modulating signal: $f_m = 1KHz$ $A_m = 1V$
Modulation Constant = 5KHz/V

Modulating Signal:



Spectrum Analyser:

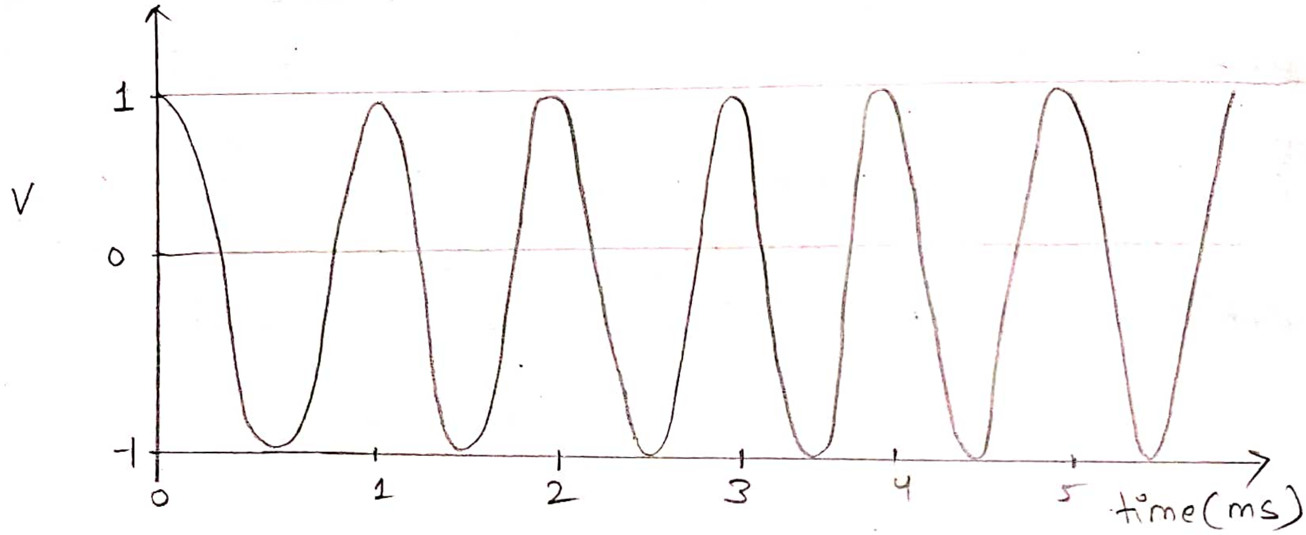


2) Carrier : $f_c = 5\,KHz$ $A_c = 1V$

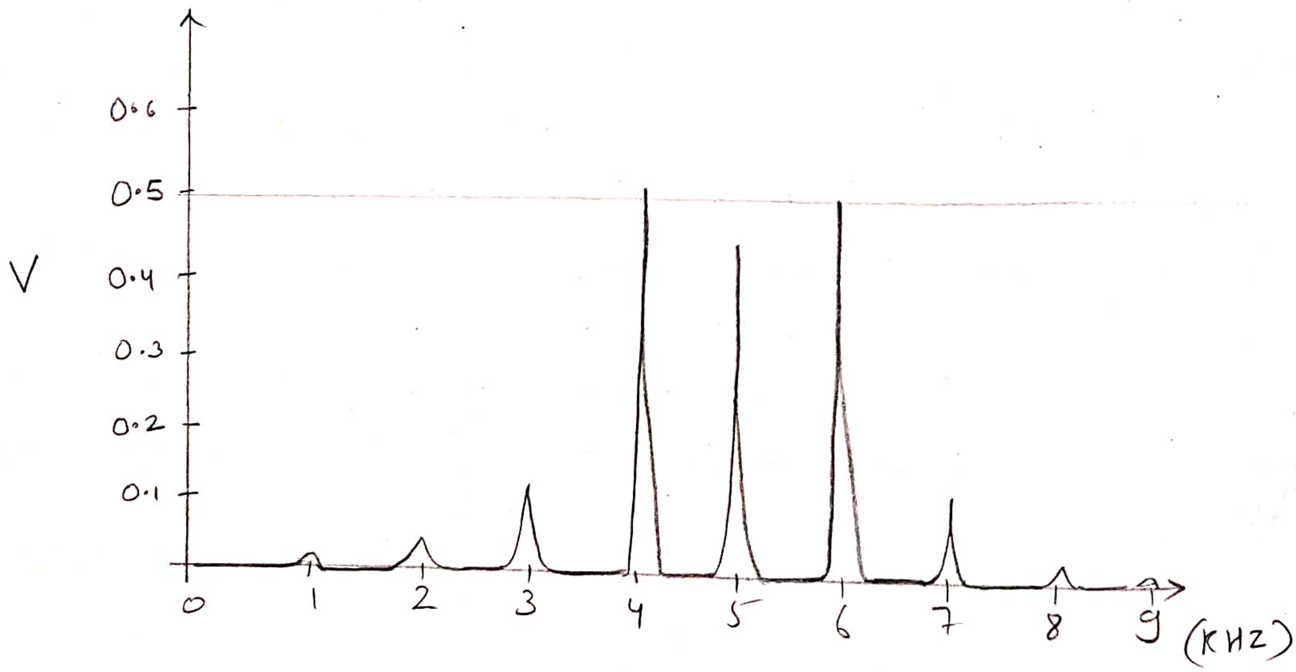
Modulating Signal : $f_m = 1\,KHz$ $A_m = 1V$

Modulation Constant = $7.5\,KHz/V$

Modulating Signal →

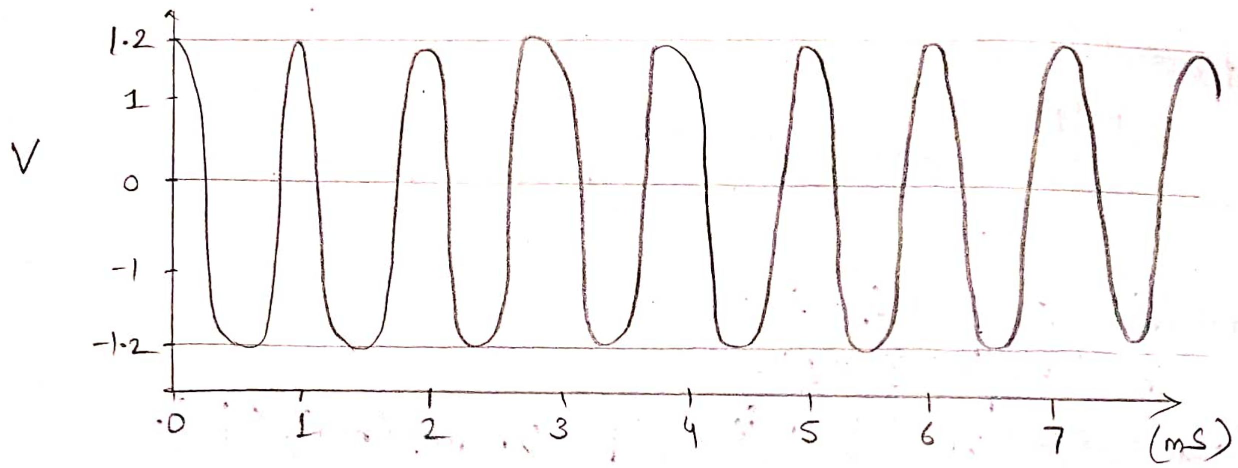


Spectrum Analyser →

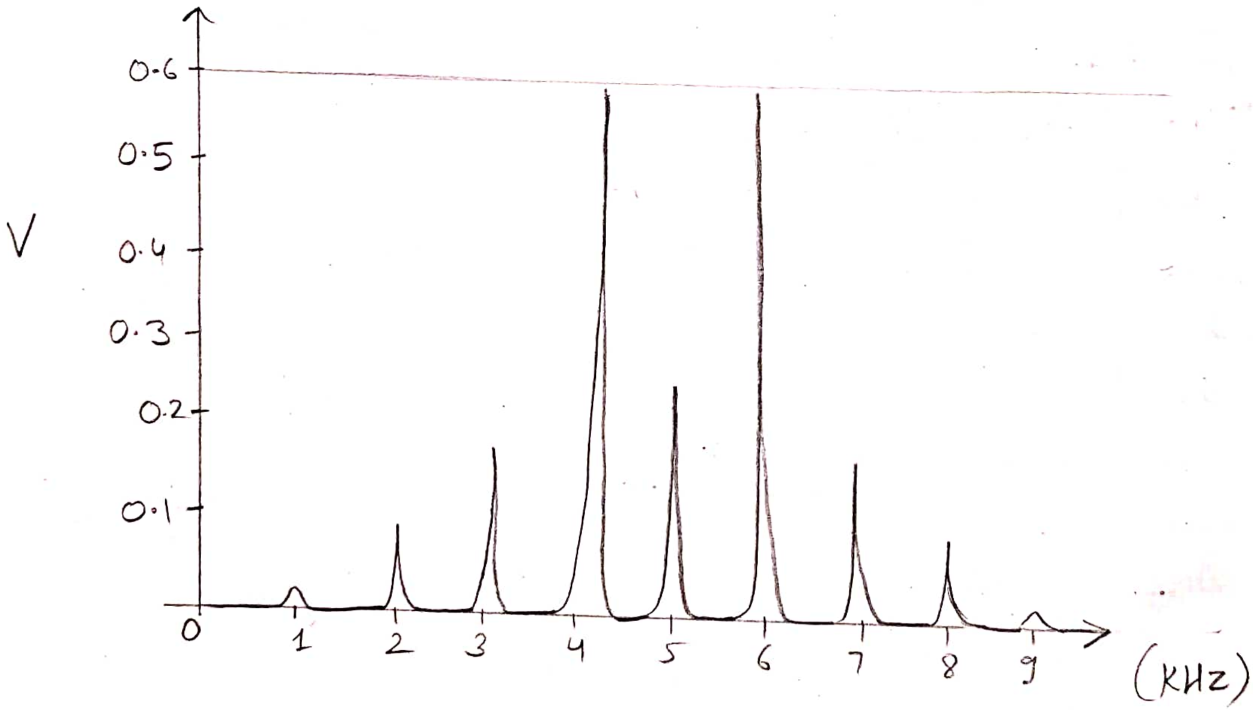


3) Carrier : $f_c = 5KHz$ $A_c = 1V$
Modulating Signal : $f_m = 1KHz$ $A_m = 1.2V$
Modulation Constant = 8.8 KHz/V

Modulating Signal →

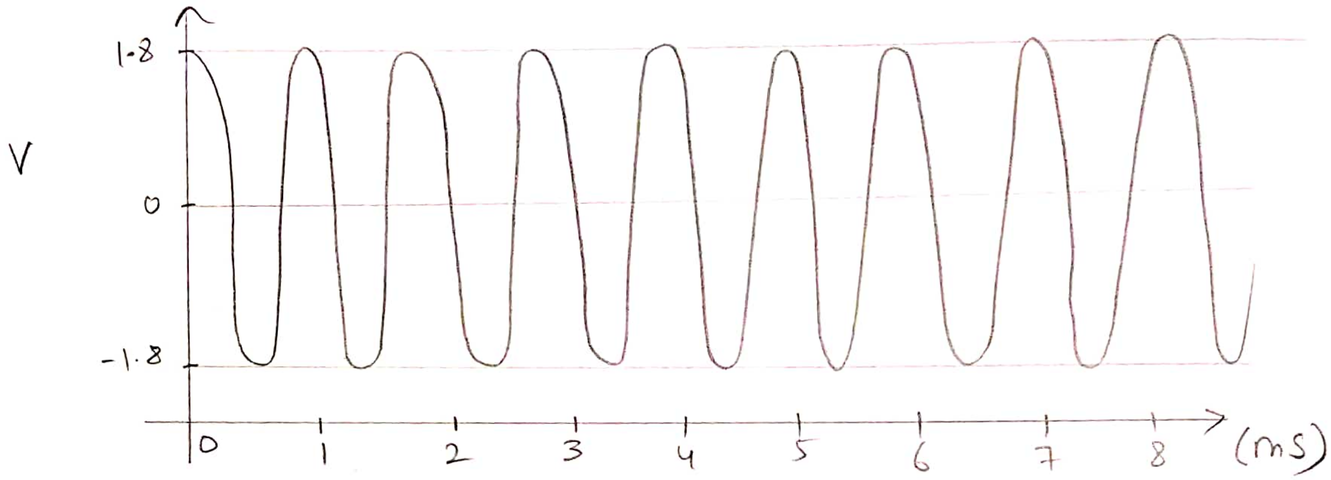


Spectrum Analyser →

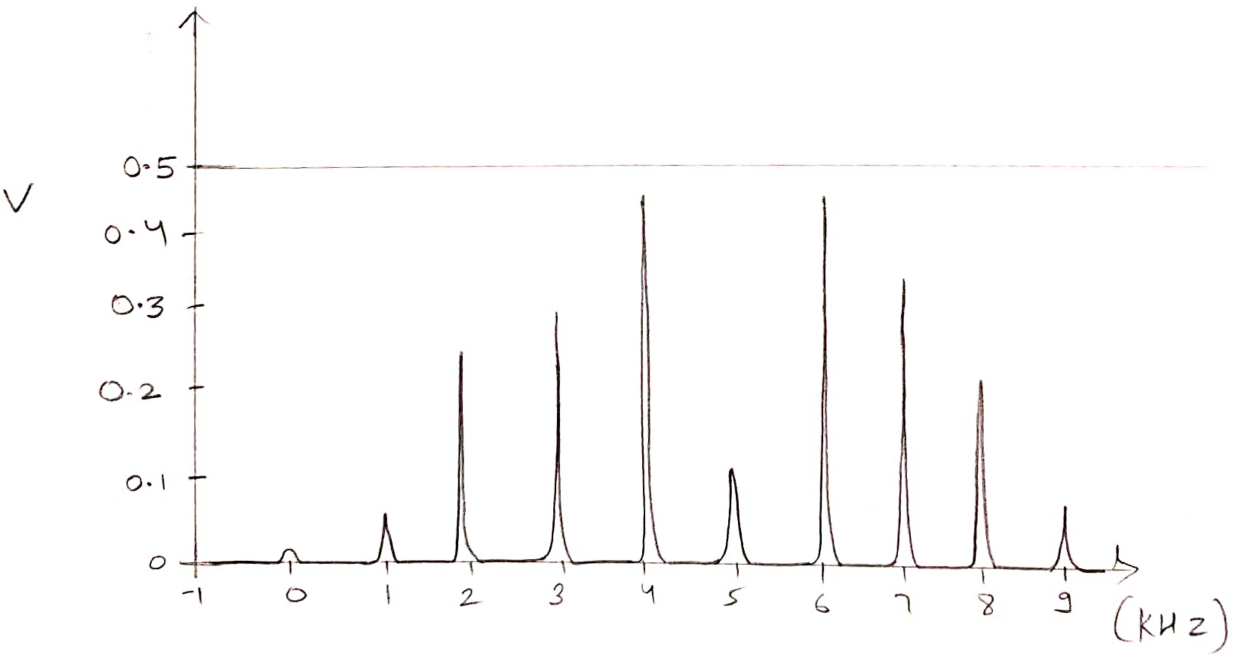


4) Carrier: $f_c = 5\text{KHz}$ $A_c = 1\text{V}$
Modulating Signal: $f_m = 1\text{KHz}$ $A_m = 1.8\text{V}$
Modulation Constant $= 9\text{ KHz/V}$

Modulating Signal →



Spectrum Analyser →

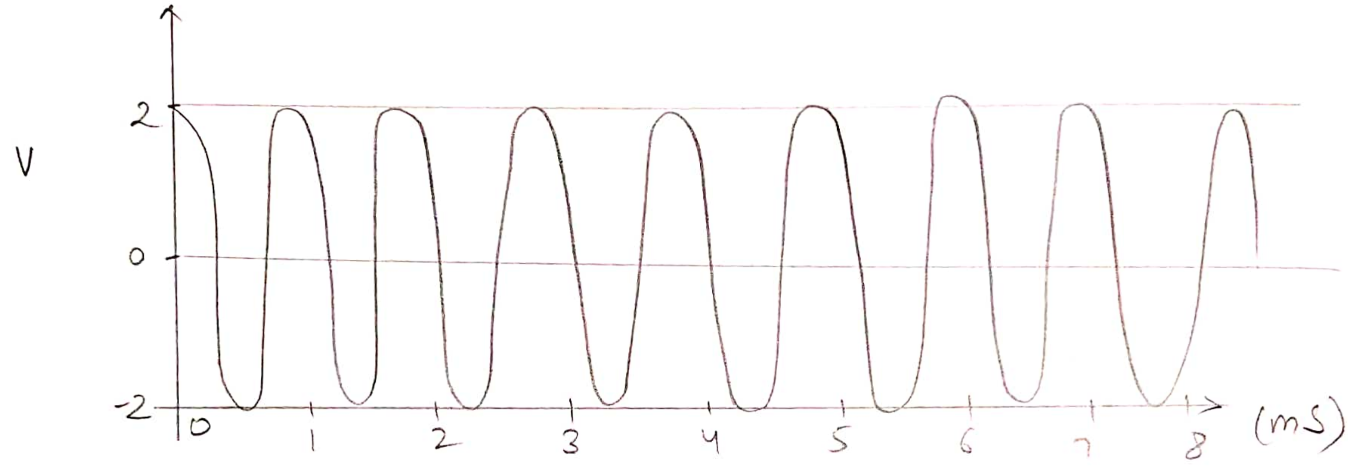


5) Carrier : $f_c = 5KHz$ $A_c = 1V$

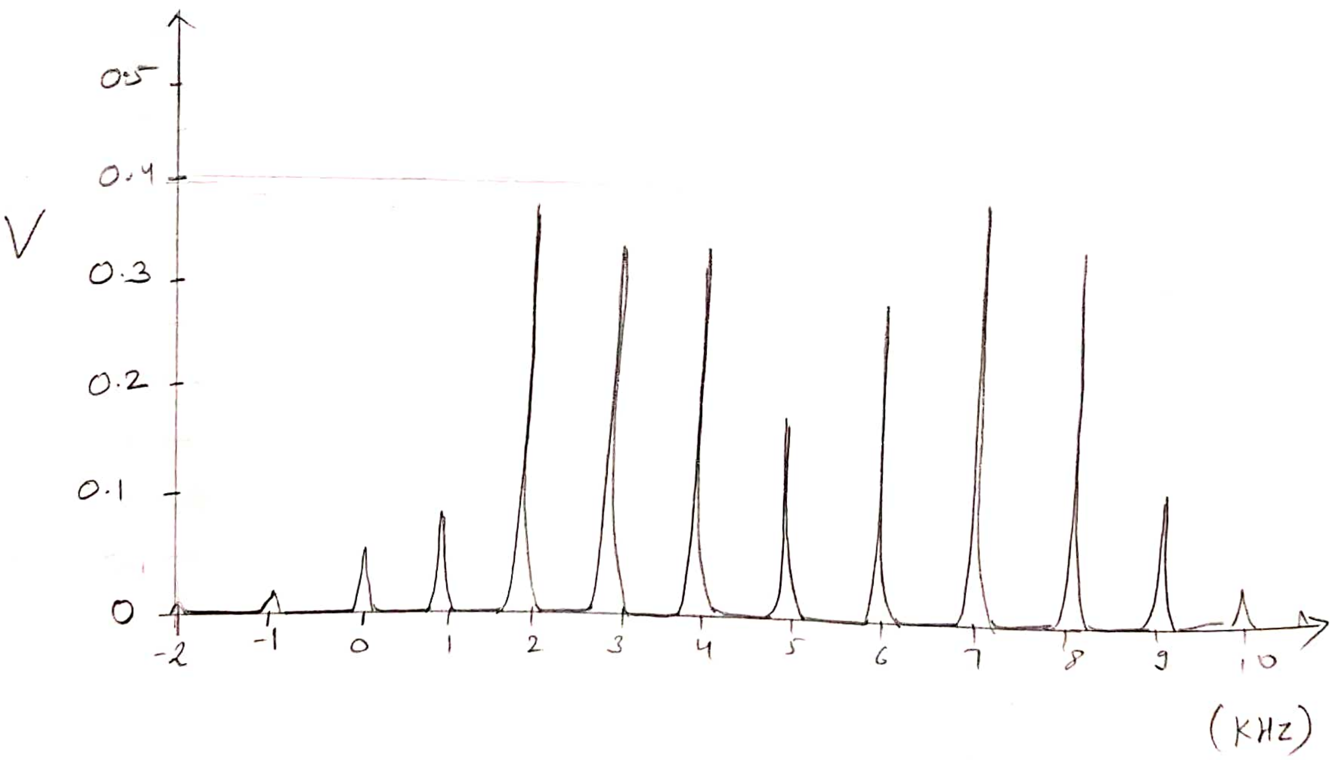
Modulating signal : $f_m = 1KHz$ $A_m = 2V$

Modulation constant = 9.3 KHz/V

Modulating Signal→



Spectrum Analyser→



Date

Expt. No. 4 Page No. 65

Applications and advantages of FM:

1) FM is resilient to noise and interference. Therefore it is used for high quality broadcast transmission.
2) FM is ideal for mobile radio communication application including more general two way radio communication or portable applications where signal levels are likely to vary considerably.
3) It is used in magnetic tape system record synthesis
4) Radar, Telemetry, observing infants for seizure through ECG, music

Conclusion:

Successfully demonstrated frequency modulation and demodulation process by observing the waveforms in time domain and their spectra in frequency domain by varying parameters of message signal.