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EXPERIMENT 4:

FREQUENCY MODULATION AND DEMODULATION

AIM: To study Frequency Modulation (F.M.) and Frequency demodulation with its Application

APPARATUS REQUIRED: LabAlive Software, MATLAB Software (online Mode)

THEORY:

(1) Angle modulation is the process in which the frequency or phase of the carrier varies according to message signal.

(2) The standard Equation of the Angle Modulated wave is

$$s(t) = A_c \cos(\theta_i(t))$$

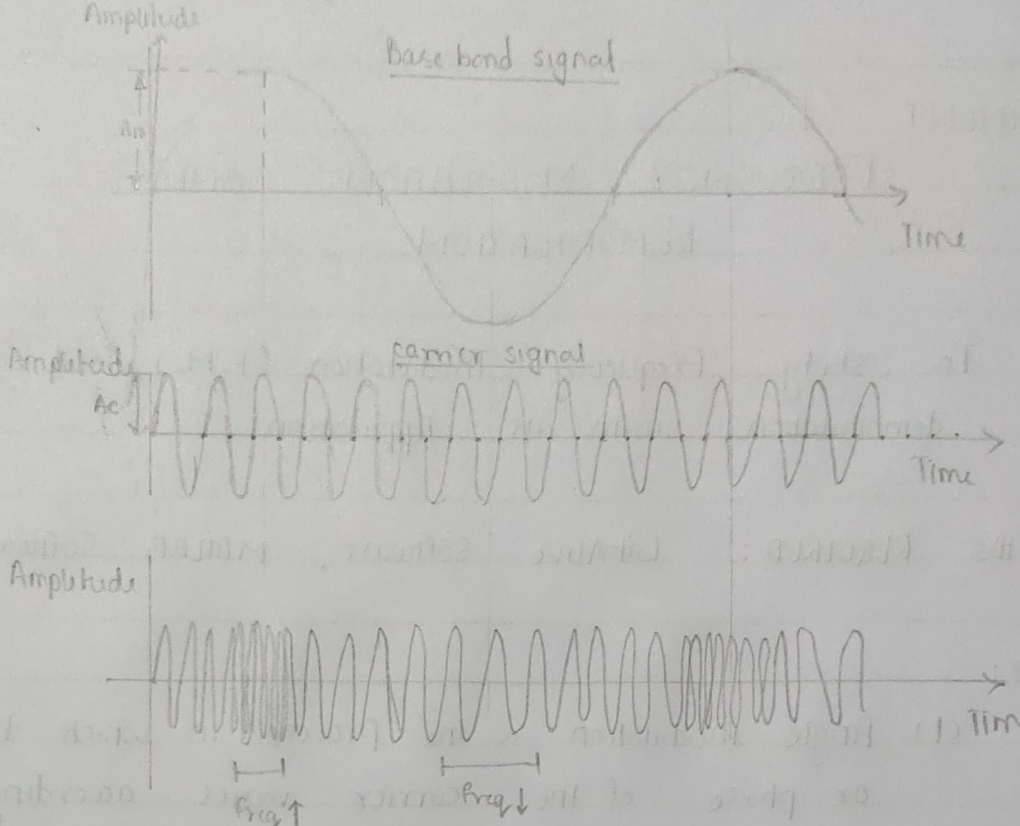
where A_c = Amplitude of the modulated wave / carrier signal
$\theta_i(t)$ = Angle of modulated wave.

(3) Angle modulation is further divided into Frequency modulation and Phase modulation

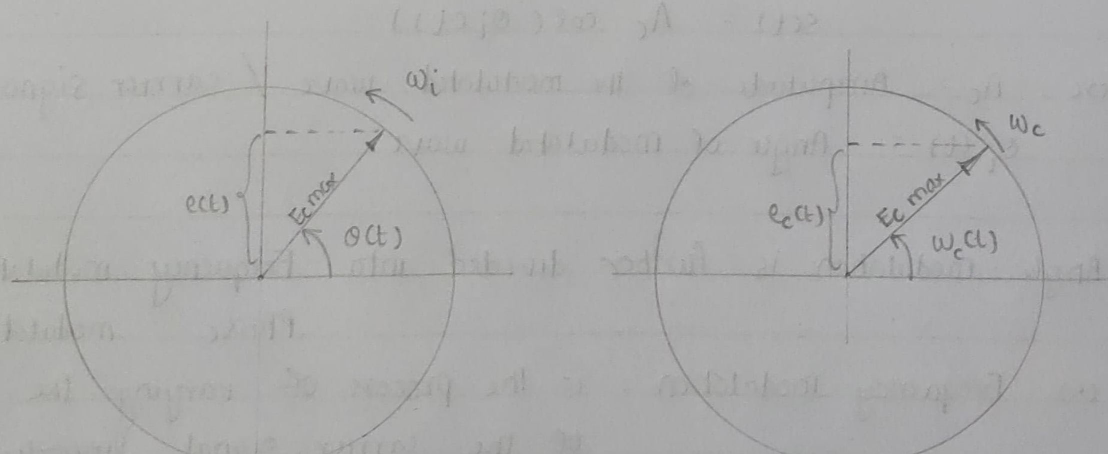
(i) Frequency modulation: is the process of varying the frequency of the carrier signal linearly with message signal.

(ii) Phase modulation: is the process of varying the phase of carrier signal linearly with message signal.

Teacher's Signature:



Frequency Modulated wave



(a) Instantaneous angular velocity $\omega_i(t)$

Rotating phasor representation of carrier of amplitude $E_c\ max$

(b) at constant angular velocity (ω_c)

(4) As The frequency of modulated wave increases, when the Amplitude of the modulating or message signal increases.
Similarly, the frequency of modulated wave decreases, when the amplitude of the modulating signal decreases.

Note: The frequency of modulated (carrier) wave remains constant and is equal to frequency of carrier signal, when Amplitude of modulating signal is zero.

(5) Mathematically,
The equation for instantaneous frequency f_i in FM modulation

$$\boxed{f_i = \underbrace{f_c}_{\text{carrier frequency}} + \underbrace{(K_f)}_{\text{frequency sensitivity}} \underbrace{m(t)}_{\text{message signal}}} \quad \text{— ①}$$

(6) We know relationship between w_i and $\theta_i(t)$

$$\left[w_i = \frac{d(\theta_i)}{dt} \right] \quad \text{— ②}$$

$$2\pi f_i = \frac{d(\theta_i)}{dt}$$

$$\theta_i(t) = 2\pi \int (f_i) dt$$

Substitute f_i from eqn ①

$$\theta_i(t) = 2\pi \int (f_c + k_f\, m(t))\, dt$$

$$\boxed{\theta_i(t) = 2\pi f_c t + 2\pi k_f \int m(t) dt} \quad \text{— ③}$$

Substitute $\theta_i(t)$ value in standard eqn of Angle Modulated wave;

$$\boxed{s(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int m(t)\, dt\right)} \quad (\text{Eqn of FM wave}) \quad ④$$

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(7) Finally, Equation of F.M. wave

$$s(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int m(t)\,dt\right) \quad \text{—} (4)$$

If modulating signal $m(t) = A_m \cos(2\pi f_m t)$, then eqn of F.M.

$$\boxed{s(t) = A_c \cos\left(2\pi f_c t + \beta \sin(2\pi f_m t)\right)} \quad \text{—} (5)$$

$$\boxed{\beta = \frac{k_f A_m}{f_m} = \frac{\Delta f}{f_m} = \text{modulation index}}$$

(8) The difference between FM modulated frequency (instantaneous frequency) and normal carrier frequency is termed as Frequency Deviation. It is denoted by $[\Delta f = f_i - f_c = k_f A_m]$ and is equal to product of k_f and A_m.

(9) FM can be divided into Narrowband F.M. and Wideband F.M. based on values of modulating index. (β)

(10) The amount of change in carrier frequency produced, by the amplitude of input modulating signal, is called frequency deviation.

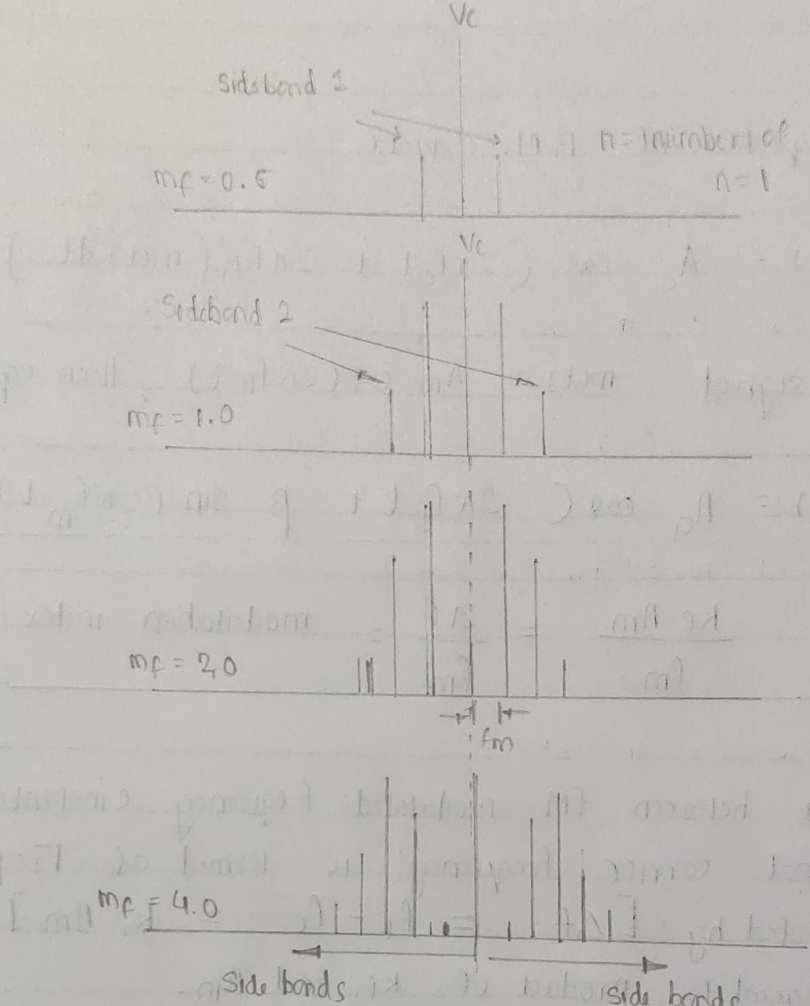
carrier frequency swings between f_{max} and f_{min} as input varies.

freq. deviation

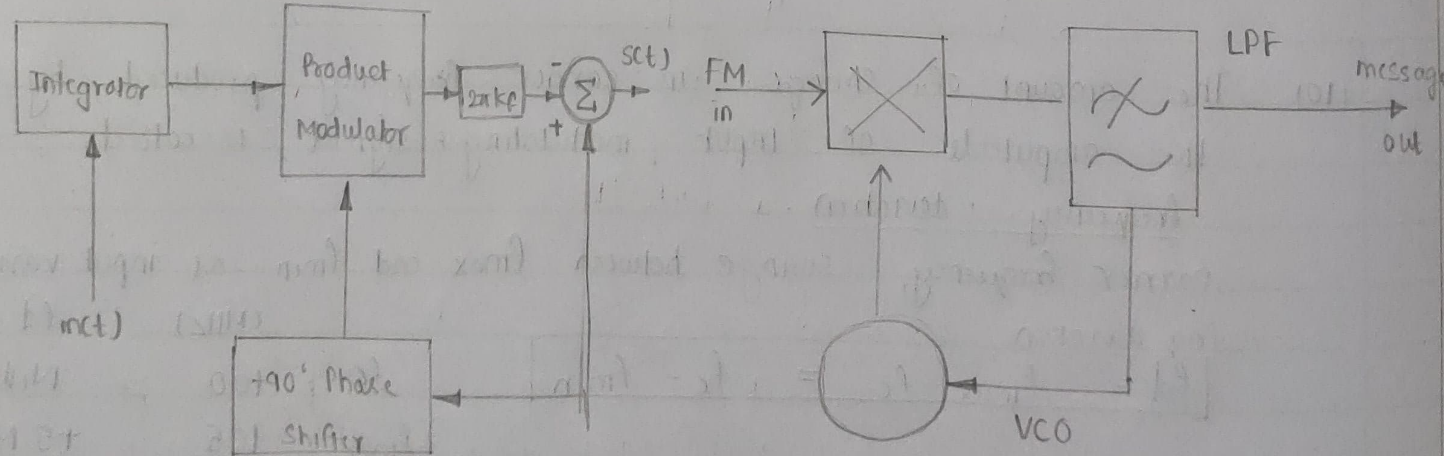
$$\boxed{f_d = f_{max} - f_c = f_c - f_{min}}$$

	(MHz)	Carrier fd from
f_c	100	Nill
f_{max}	105	+5 MHz
f_{min}	95	- 5 MHz

Teacher's Signature:



How spectrum F.M. varies with mf



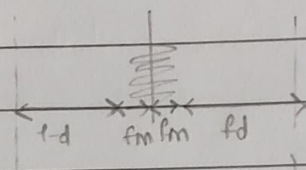
Block diagram of FM modulator and demodulator

(11) F.M. signal spectrum is quite complex and will have infinite number of side band as shown in figure.

This figure gives an idea, how the spectrum expands as the modulation index increases.

Side bands are seperated from carrier by $f_c \pm f_m$, $f_c \pm 2f_m$, $f_c \pm 3f_m$, and so on...

$$\boxed{\text{Bandwidth} = 2 * (f_m + \Delta f)}$$



(12) In F.M., carrier Amplitude is constant,
∴ Transmitted Power is constant.
& Transmitted Power does not depend on modulation index.

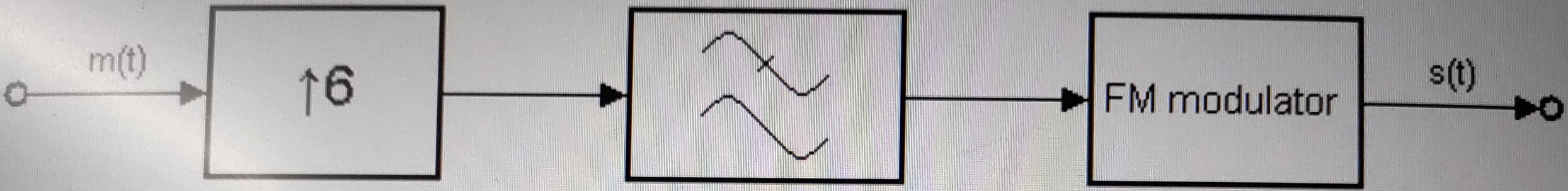
(13) F.M. has better noise immunity. FM is rugged / robust against noise ∴ The quality of FM will be good even in presence of noise.

(14) Applications & Advantages of F.M.

(A) FM is recilient to noise and interference. ∴ It is used for high quality broadcast transmission.

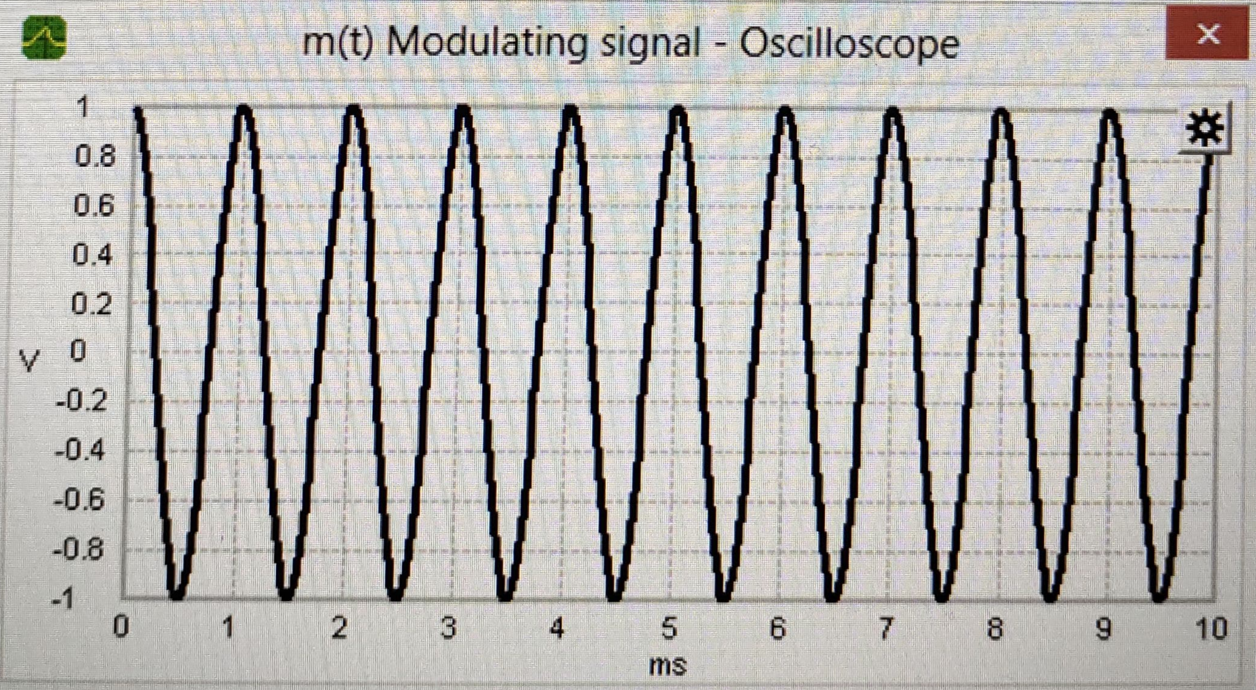
(B) FM is ideal for mobile radio communication application including more general two way radio communication or portable applications where signal levels are likely to vary considerably. (magnetic tape record system)

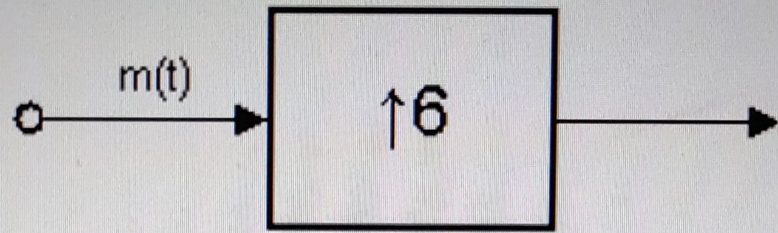
(C) Radar, Telemetry, observing infants for seizure through EEG, music synthesis

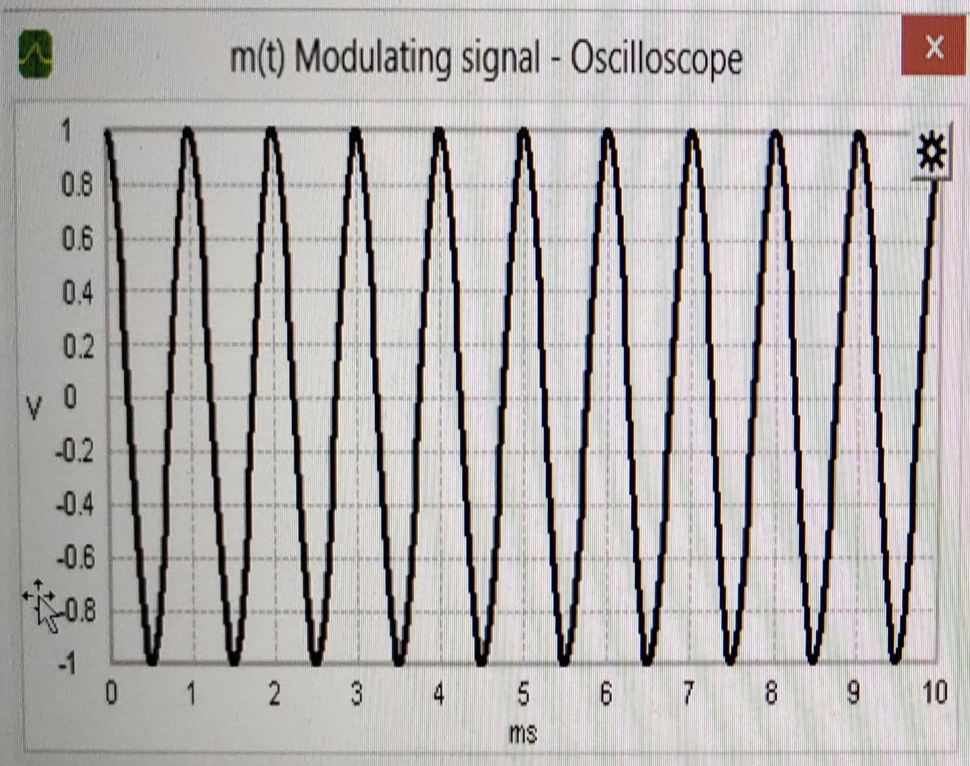


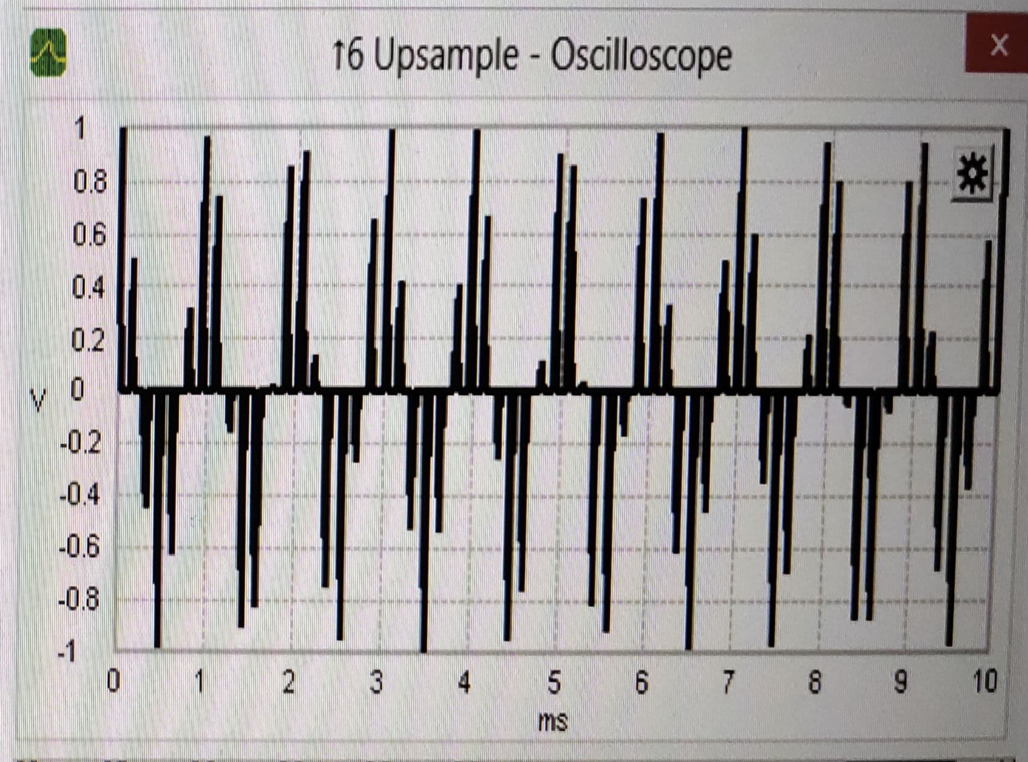
Signal Generator - Properties

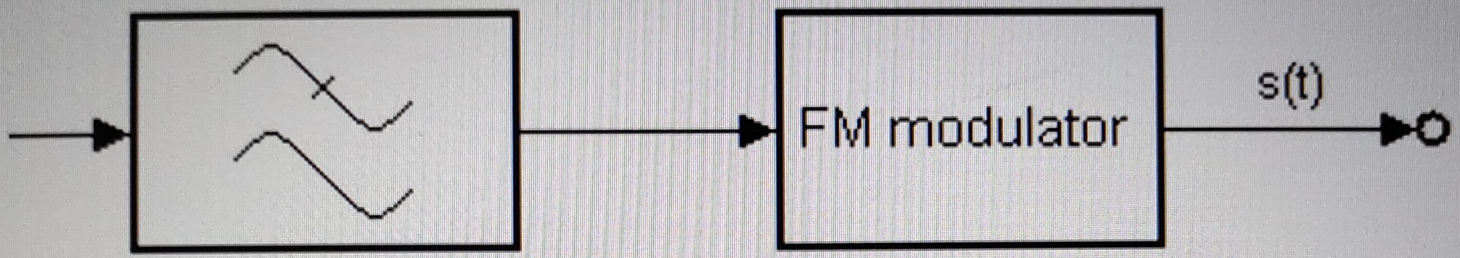
Amplitude	1.0	V
Frequency	1.0	kHz
Output	On	
Waveform	Cosine	

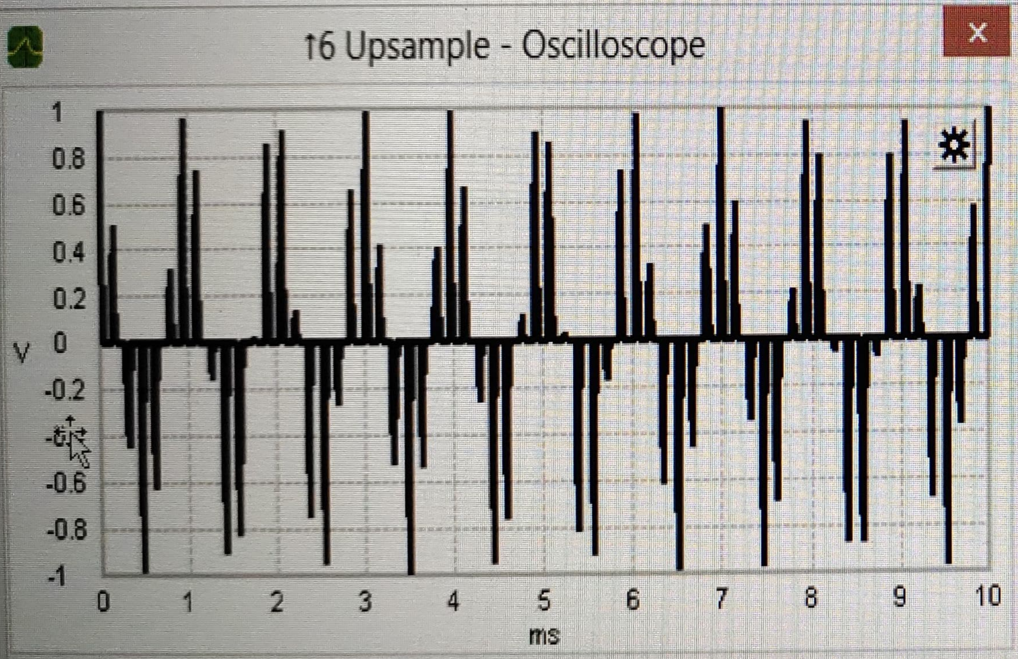


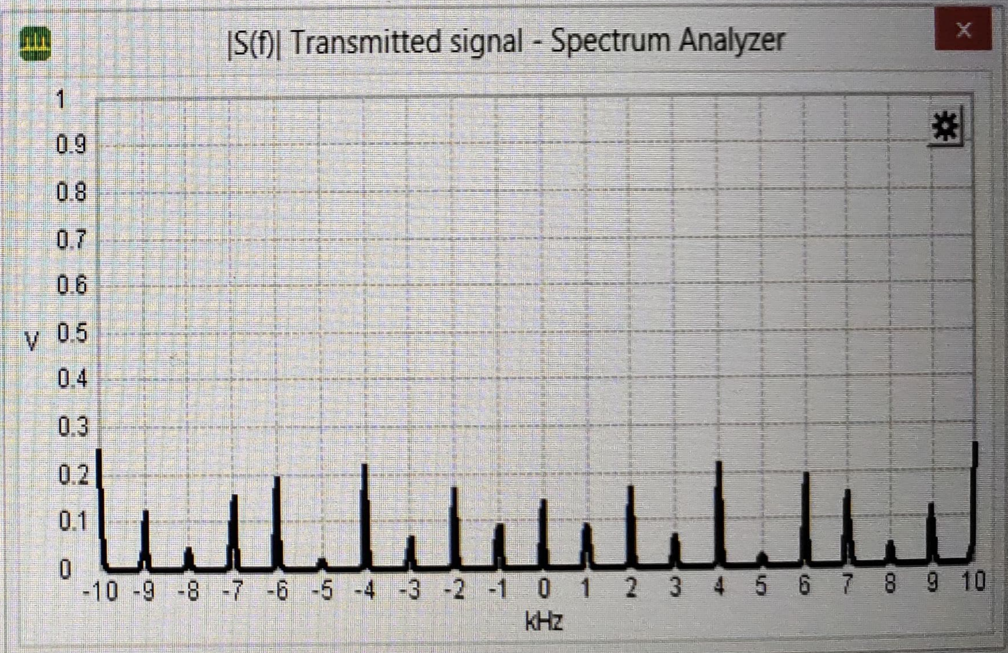

m(t)
↑6

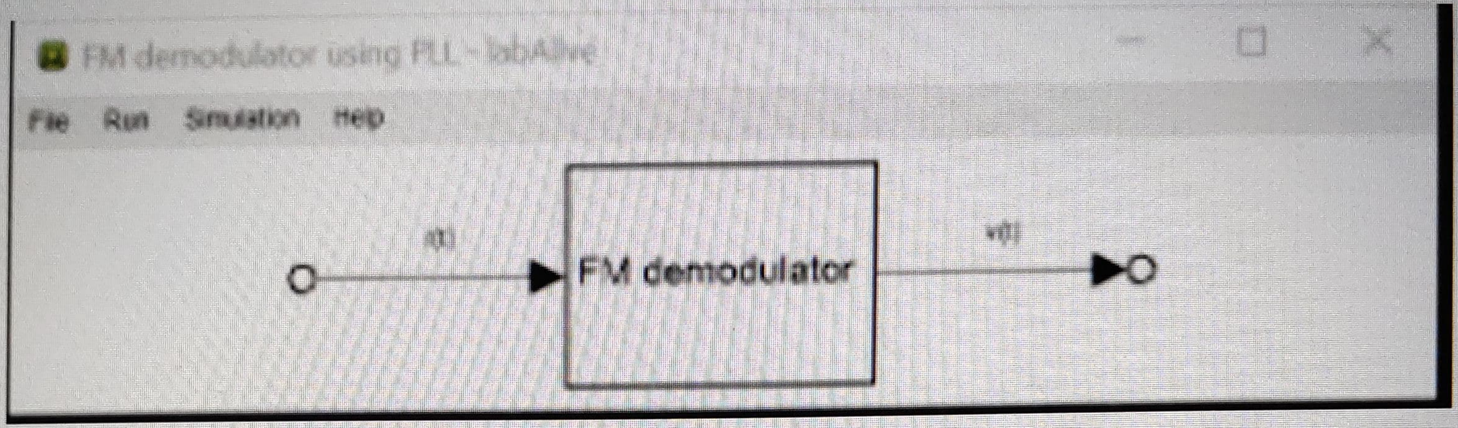

m(t) Modulating signal - Oscilloscope
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
V
0 1 2 3 4 5 6 7 8 9 10
ms

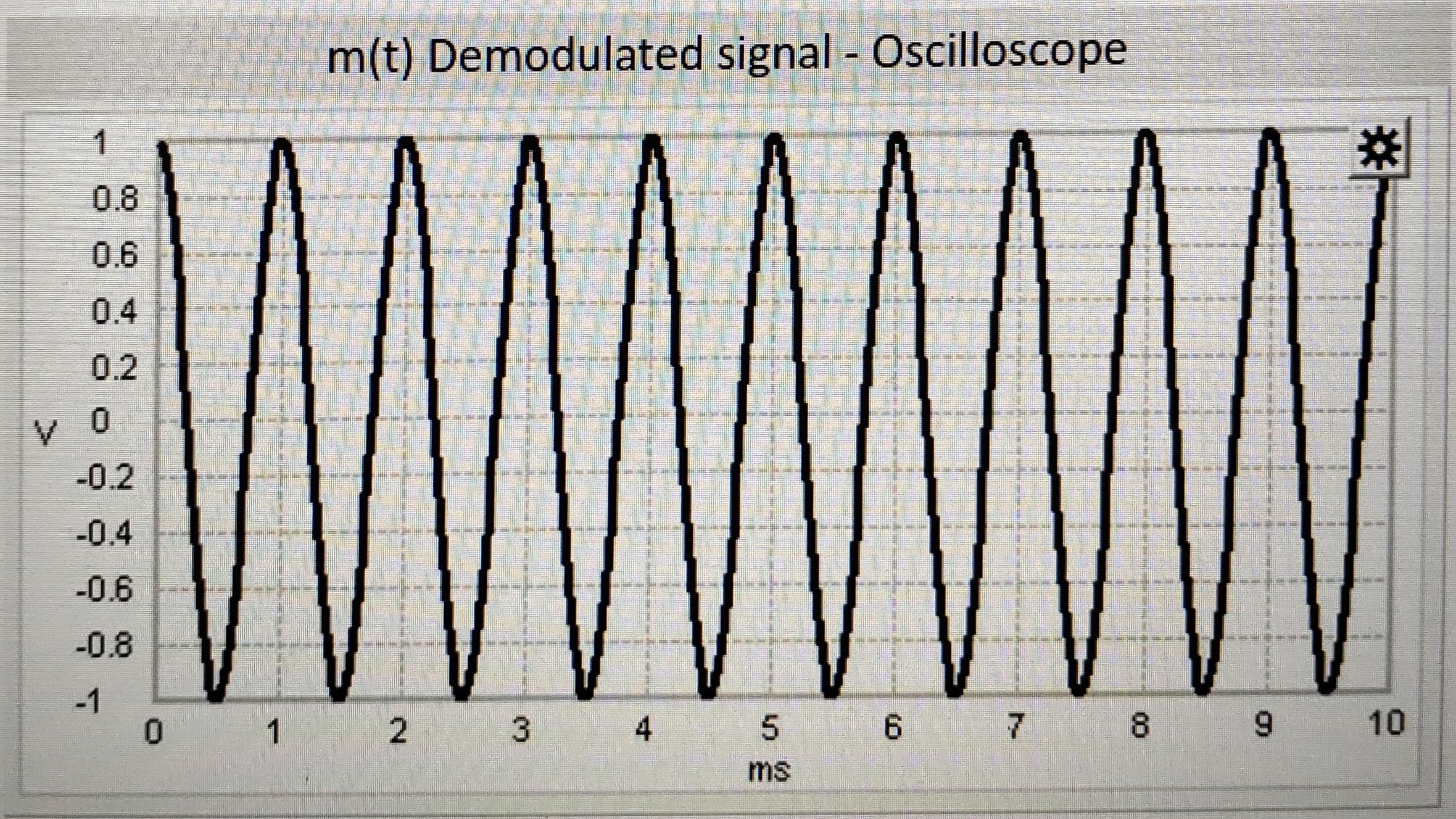

↑6 Upsample - Oscilloscope
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
V
0 1 2 3 4 5 6 7 8 9 10
ms


FM modulator
s(t)


↑6 Upsample - Oscilloscope
1
0.8
0.6
0.4
0.2
0
-0.2
-0.6
-0.8
-1
V
0 1 2 3 4 5 6 7 8 9 10
ms


|S(f)| Transmitted signal - Spectrum Analyzer
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
V
-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10
kHz


FM demodulator using PLL - labAlive
File
Run
Simulation
Help
FM demodulator

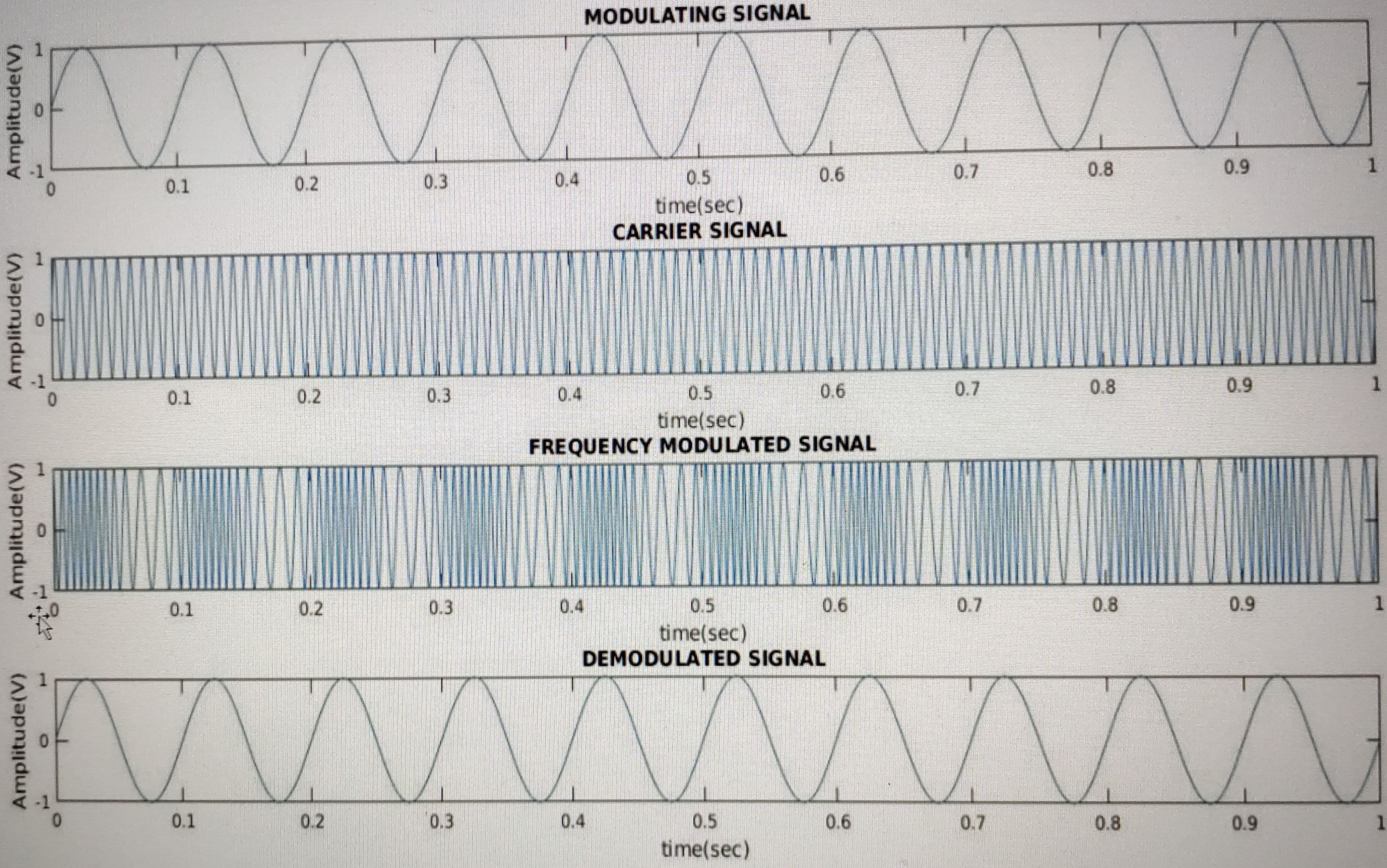

m(t) Demodulated signal - Oscilloscope
V
ms
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
1
2
3
4
5
6
7
8
9
10

MatLab Code

```matlab
% Plot the frequency modulated signal
fc=100;
fm=5;
ts=1/(10*fc);
fs=(1/ts);
kf=2; % Frequency deviation sensitivity
wc=2*pi*fc;
t=0:ts:2;
m=sin(2*pi*fm*t);
y=cos(wc*t+(kf*2*pi*cumsum(m)).*ts);
figure(1)
subplot(211)
plot(t,m)
title('Input signal')
subplot(212)
plot(t,y)
title('FM modulation of input signal')
```

FM Modulation

```
% Plot the frequency response
mf=fftshift(fft(m))*ts;
delta=fs/length(mf);
f=-fs/2:delta:fs/2-delta;
figure(2)
subplot(211)
plot(f,abs(mf))
title('Magnitude spectrum of input signal')
a=fftshift(fft(y))*ts;
delta=fs/length(a);
f=-fs/2:delta:fs/2-delta;
subplot(212)
plot(f,abs(a))
title('Magnitude spectrum of the fm')
```


MODULATING SIGNAL
Amplitude(V)
1
0
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
time(sec)
CARRIER SIGNAL
Amplitude(V)
time(sec)
FREQUENCY MODULATED SIGNAL
Amplitude(V)
time(sec)
DEMODULATED SIGNAL
Amplitude(V)
time(sec)