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194107 / ECE-A

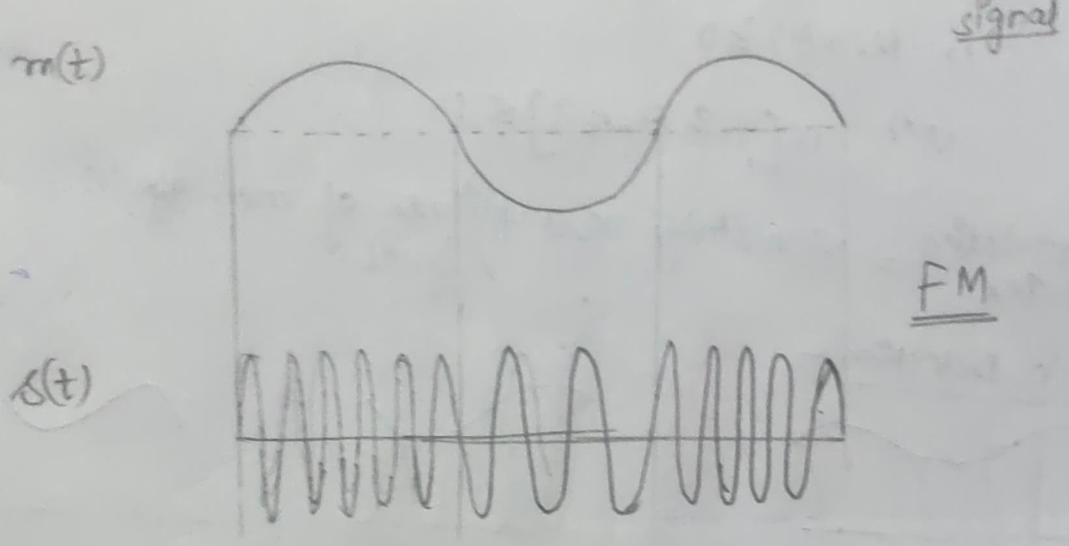
Comm. Sys. LAB

Experiment - 2.

AIM: To study frequency modulation and simulate the modulation and demodulation of different signal.

Software: MATLAB R2021b

Theory: Frequency Modulation (FM) is the encoding of information in a carrier wave by varying the instantaneous frequency of wave.



* Modulated Frequency

$$f_i(t) = f_c + k_f (m(t))$$

unit of k_f is Hertz/volts.

→ the frequency of modulated wave increases, when the amplitude of modulating signal increases

→ FM is widely used for radio broadcast, radar, telemetry, seismic propecting

→ It has larger Signal-to-Noise ratio (SNR) and rejects frequency interference better that AM signal.

Expression of FM signal-

$$s(t) = A_c \cos\left(2\pi f_c t + 2\pi K_f \int_0^t m(\tau)\, dt\right)$$

Since, we know frequency is rate of change of phase we can write phase of FM signal as ie

$$f_i(t) = \frac{1}{2\pi} \frac{d\theta_i(t)}{dt}$$

$$\theta_i(t) = 2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\, d\tau.$$

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

then, instantaneous frequency,

$$f_i(t) = f_c + K_f\, m(t) = f_c + K_f A_m \cos(2\pi f_m t)$$

Maximum Frequency Deviation-

$$\Delta f = \max|f_i(t) - f_c| = \max|K_f A_m \cos(2\pi f_m t)|$$

$$\boxed{\Delta f = K_f A_m}$$

Demodulation of FM Signals-

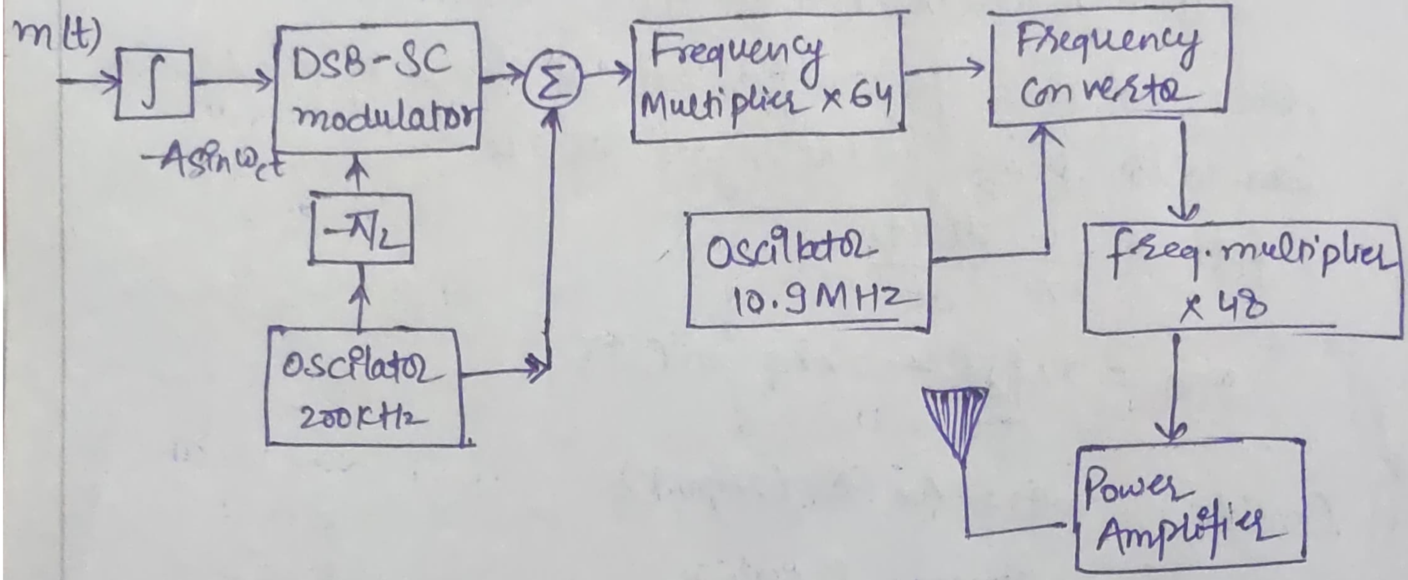
Information in FM signal resides in $\omega_i = \omega_c + \omega_f\, m(t)$

Hence, a frequency selective network with transfer function, $|H_i(f)| = 2a\pi f + f$ over FM band would yield an output proportional to instantaneous frequency.

$$\phi_{Fm}(t) = \frac{d}{dt}\left\{ A_c \cos\left[\omega_c t + k_f \int_{-\infty}^{t} m(\tau)\, d\tau\right]\right\}$$

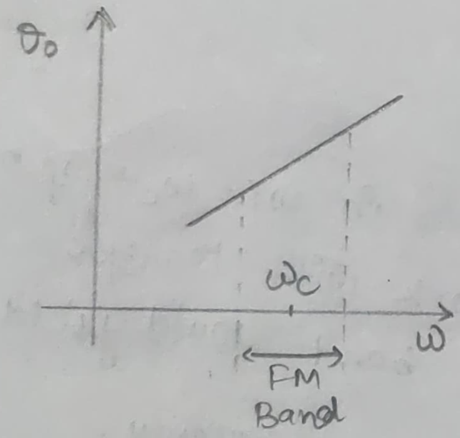
$$= A_c\left[\omega_c + k_f\, m(t)\right] \sin\left(\omega_c t + k_f \int_{-\infty}^{t} m(\tau)\, d\tau - \pi\right)$$

→ FM Generation using Armstrong Method –

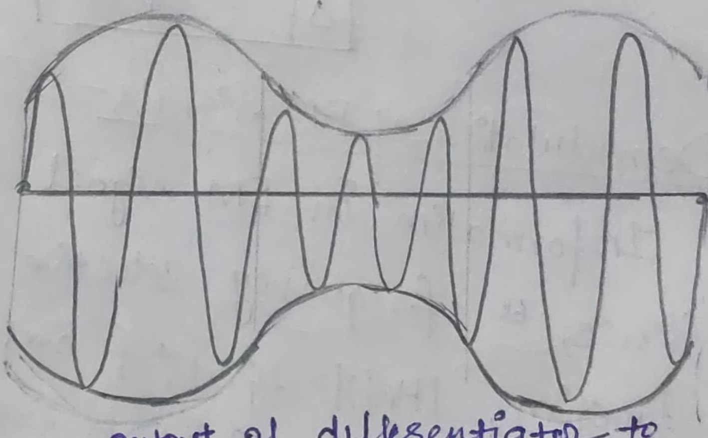


[Block Diagram]

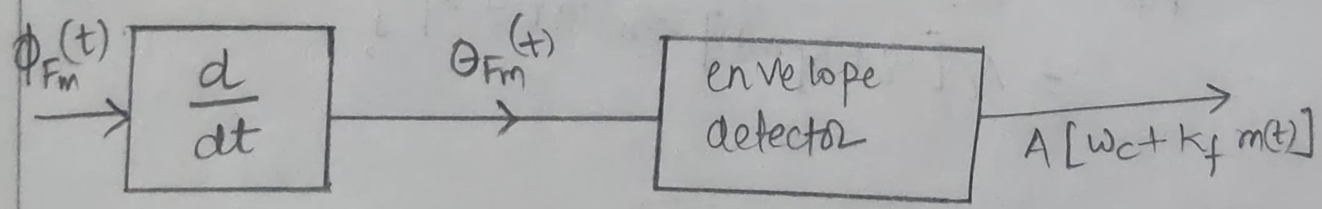
→ FM Demodulation by Direct Differentiation →



FM demodulator frequency response.



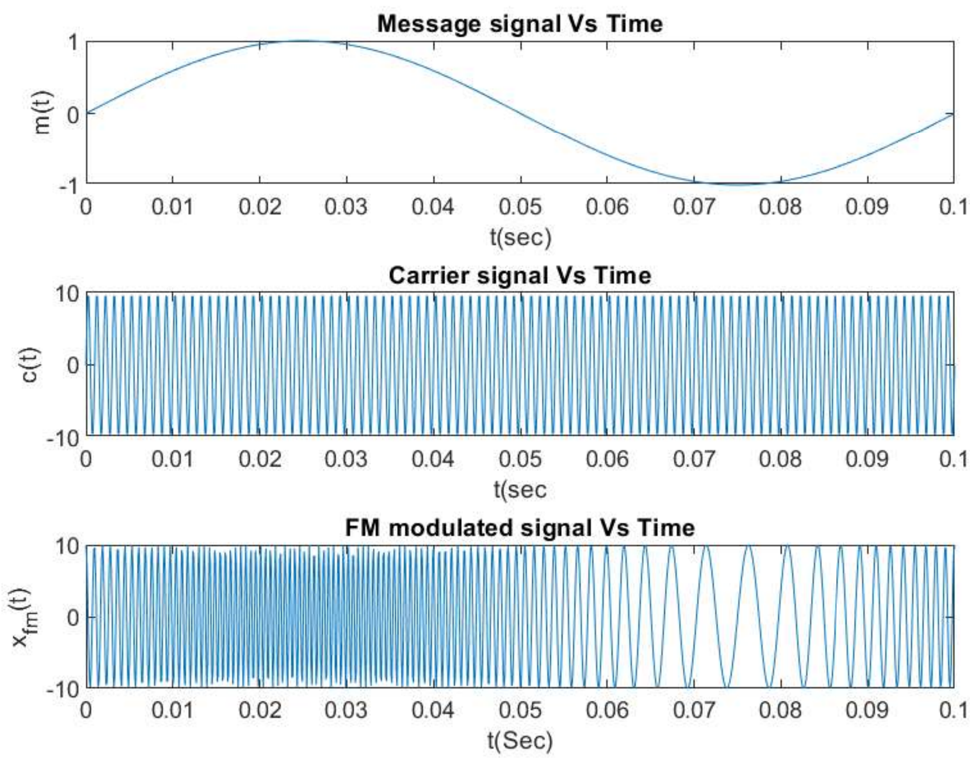
output of differentiator to the input FM wave.

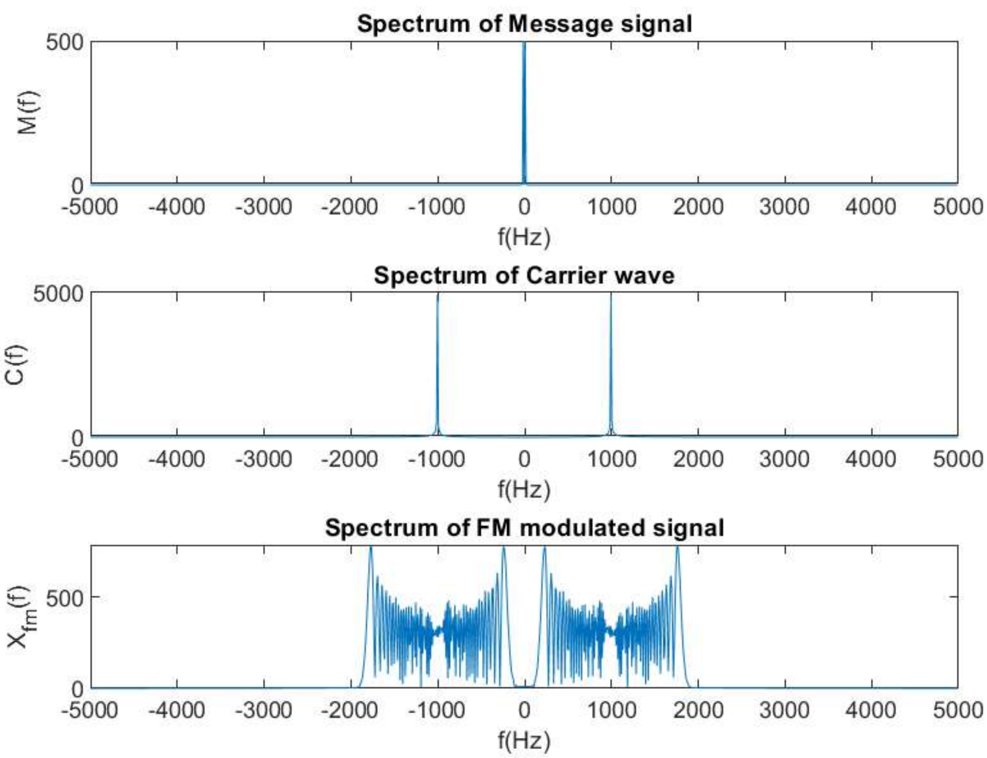


FM Demodulation by direct differentiation.

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Author: Amit Kumar Yadav
% Roll No : 194107 (ECE-A)
% Lab Date : 24-01-2022
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%FM modulation
Ac=10; %amplitude of carrier wave
fm=10; %frequency of message signal (Hz)
fc=1000; %carrier frequency (Hz)
F=10000; %sampling frequency (Hz)
kf=800; %frequency sensitivity
mi=kf/fm; % modulation index
T=1/F;
t=0:T:0.1;% time vector

%1.Message signal
m=sin(2*pi*fm*t);
figure(1);
subplot(311); % plot at 1st position in a 3-by-1 grid
plot(t,m); xlabel('t(sec)'); ylabel('m(t)');
title('Message signal Vs Time')

%Plotting Spectrum of message signal
n=length(m); %length returns period of the message signal
M=fftshift(fft(m,n)); %zero-centered fast fourier transform
f=F*[-n/2:n/2-1]/n; %zero-centered frequency range
figure(2);
subplot(311);
plot(f,abs(M));xlabel('f(Hz)'); ylabel('M(f)');
title('Spectrum of Message signal');

%2.Carrier wave definition
c=Ac*sin(2*pi*fc*t);
figure(1);
subplot(312);
plot(t,c); xlabel('t(sec'); ylabel('c(t)');
title('Carrier signal Vs Time');

% plotting spectrum of carrier wave
N=length(c);
C=fftshift(fft(c,N));
f=F*[-N/2:N/2-1]/N;
figure(2);
subplot(312);
plot(f,abs(C)); xlabel('f(Hz)'); ylabel('C(f)');
title('Spectrum of Carrier wave');

%3.FM modulated signal
```

```
x_fm=Ac*sin(2*pi*fc*t-(mi*cos(2*pi*fm*t)));
figure(1);
subplot(313);
plot(t,x_fm); xlabel('t(Sec)'); ylabel('x_f_m(t)');
title('FM modulated signal Vs Time' );

%Spectrum of fm modulated signal
l=length(x_fm);
X_fm=fftshift(fft(x_fm,l));
f=F*[-l/2:l/2-1]/l;
figure(2); subplot(313);
plot(f,abs(X_fm)); xlabel('f(Hz)'); ylabel('X_f_m(f)');
title('Spectrum of FM modulated signal' );
```


Message signal Vs Time
m(t)
1
0
-1
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
t(sec)
Carrier signal Vs Time
c(t)
10
0
-10
t(sec
FM modulated signal Vs Time
$x_{fm}(t)$
10
0
-10
t(Sec)


Spectrum of Message signal
M(f)
500
0
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
4000
5000
f(Hz)
Spectrum of Carrier wave
C(f)
5000
0
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
4000
5000
f(Hz)
Spectrum of FM modulated signal
$X_{fm}(f)$
500
0
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
4000
5000
f(Hz)

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Author: Amit Kumar Yadav
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%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

fs = 400; %sampling frequency 800Hz
fc = 100; %carrier frequency 200Hz
Ta = 0.04;
t = (-0.2:1/fs:0.2)'; %generating time vector

%1. message signal equation
x = triangl((t+0.04)/Ta) - triangl((t-0.04)/Ta);
figure(1);
axis([-0.04 0.04 -1.2 1.2]);
plot(t,x,'LineWidth', 1.5);
xlabel('{\it t}(sec)'); ylabel('{\it m} (t)');
title('message signal');

%set frequency deviation to 50Hz
fDev = 50;

%2. Frequency Modulation
y = fmmod(x,fc,fs,fDev);
figure(2); subplot(211);
plot(t,x,'b',t,y,'k--');
xlabel('Time (s)');
ylabel('Amplitude');
legend('Original Signal','Modulated Signal');

%3. Demodulation of FM signal
z = fmdemod(y,fc,fs,fDev);
figure(2); subplot(212);
plot(t,x,'b',t,y,'k--',t,z,'r');
xlabel('Time (s)');
ylabel('Amplitude');
legend('Original Signal','Modulated Signal', 'Demodulated Signal');
axes.ColorOrder = [0.9 0.9 0.9;0.2 0.2 0.2; 0.9 0.9 0.9];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%The triangle function is a function of time 't'
%triangl(t) = 1-|t|, if |t| < 1
%triangl(t) = 0, if |t| > 1
function y = triangl(t)
    y = (1-abs(t)).*(t>=-1).*(t<1);
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```
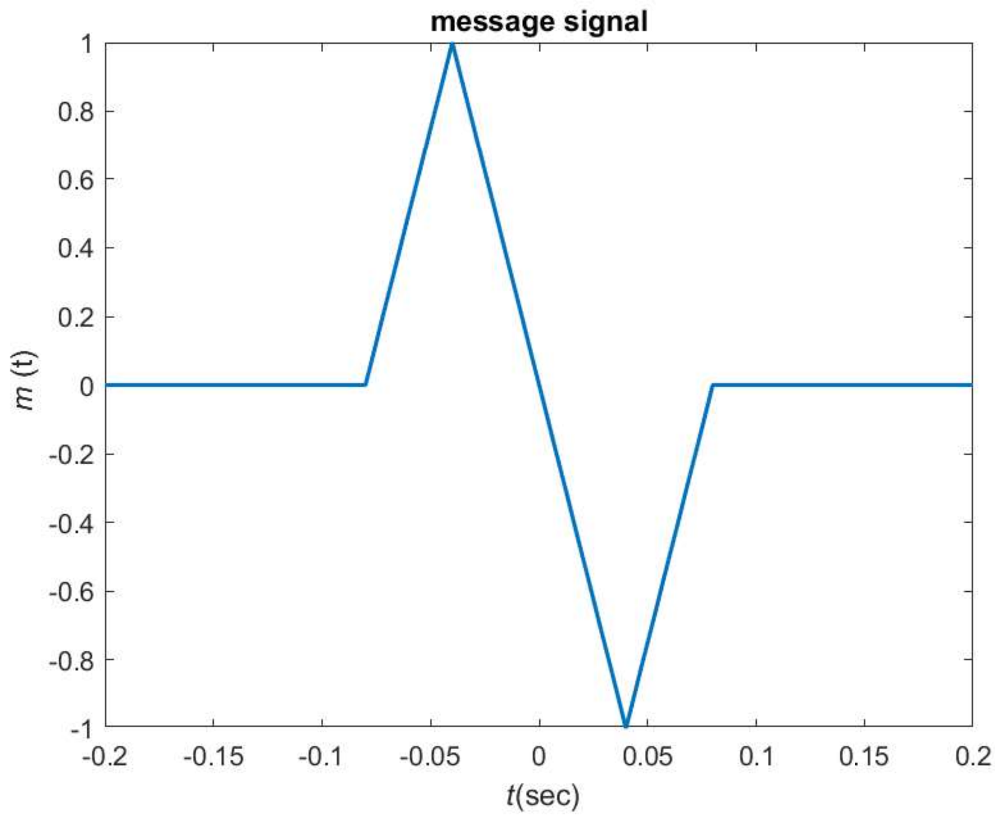
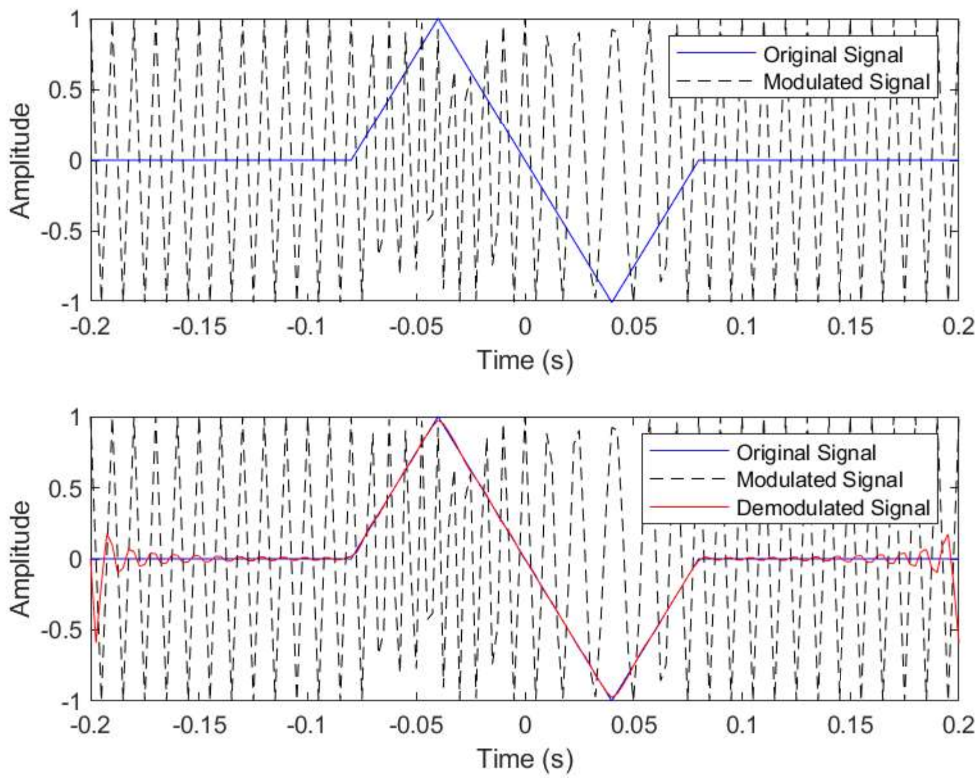


message signal
m (t)
t(sec)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2


Original Signal
Modulated Signal
Amplitude
Time (s)
Original Signal
Modulated Signal
Demodulated Signal
Amplitude
Time (s)

Results and Learning

→ First, a scratch implementation was developed for $m(t) = \sin(2\pi f_m t)$ and to get spectrum zero centered fast fourier transformed was used.

→ second, we used *MATLAB inbuilt function* "fmmod" and "fmdemod" for signal which comprised two triangular signal.

→ After simulation, it was verified that amplitude of frequency modulated wave may change based on deviation. FM permits serval independent transmitters on same frequency with neglible interference.