EE357-AM MODULATION

FERNANDO P.D.R.
E/16/103
SEMESTER 6
21/07/2021

Square Law Demodulation

AM Generation

Fm - Frequency of the messege signal
Fc - Frequency of the carrier signal
Fs -Sampling Frequency (4 x(Fm+Fc))
Len -time interval (0 to10 secs)

```
clear;
clc;
ka=input('ka');
fm=input('fm');
fc=input('fc');
len=10;
Fs=(4*(fm+fc));

t=0:1/Fs:len;
m=sin(2*pi*fm*t);
c=cos(2*pi*fc*t);
s=(1+ka*m).*c;

%fourier of modulatedd signal s
y=abs(fft(s));

%matching lengths of f and y
f=0:1/len:2*(fc+fm);
p=y(1:2*(fc+fm)*len+1);

f1=figure;
f2=figure;

figure(f1);
plot(f,p);

figure(f2);
subplot(3,1,1);
plot(t(1:100),m(1:100))
title(['messege fm =',num2str(fm),' '])

subplot(3,1,2);
plot(t(1:100),c(1:100))
title(['carrier fc = ',num2str(fc),' '])

subplot(3,1,3);
plot(t(1:100),s(1:100))
title(['modulated ka =',num2str(ka),' '])
```

Case 1

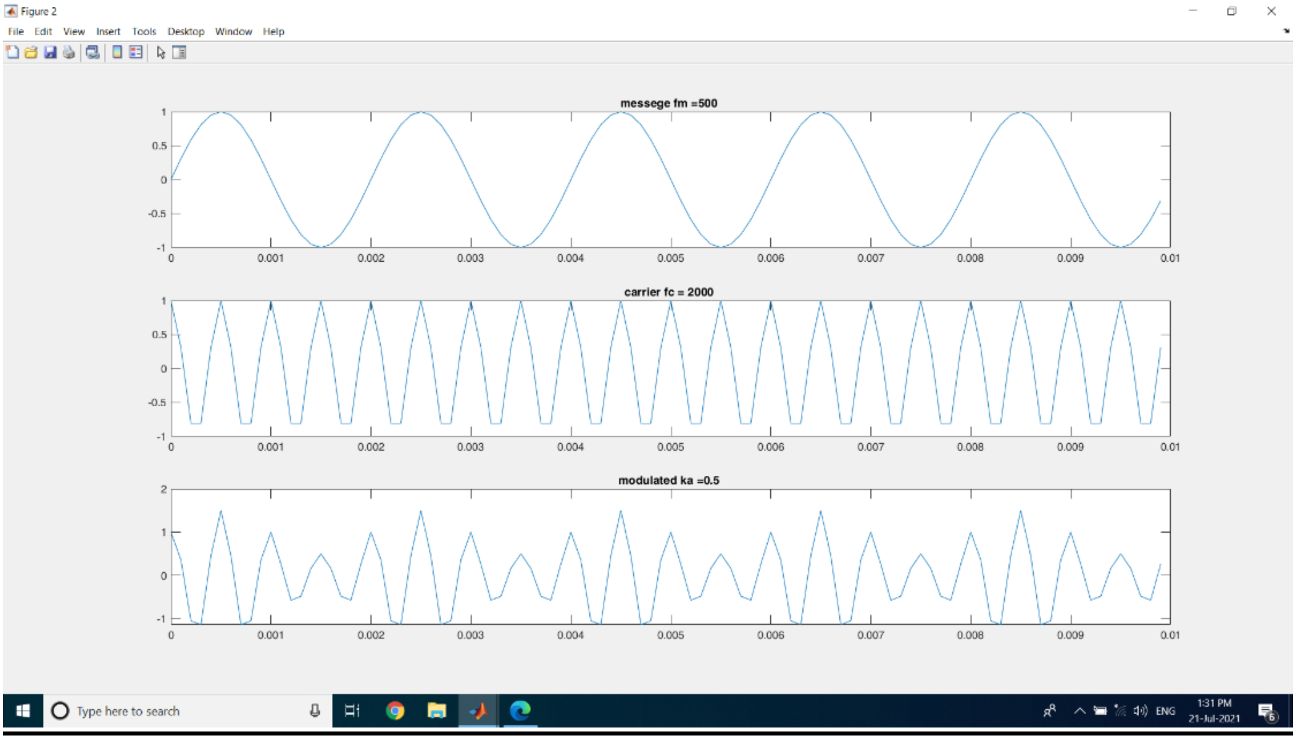

Figure 1 – Plot of the signal 1

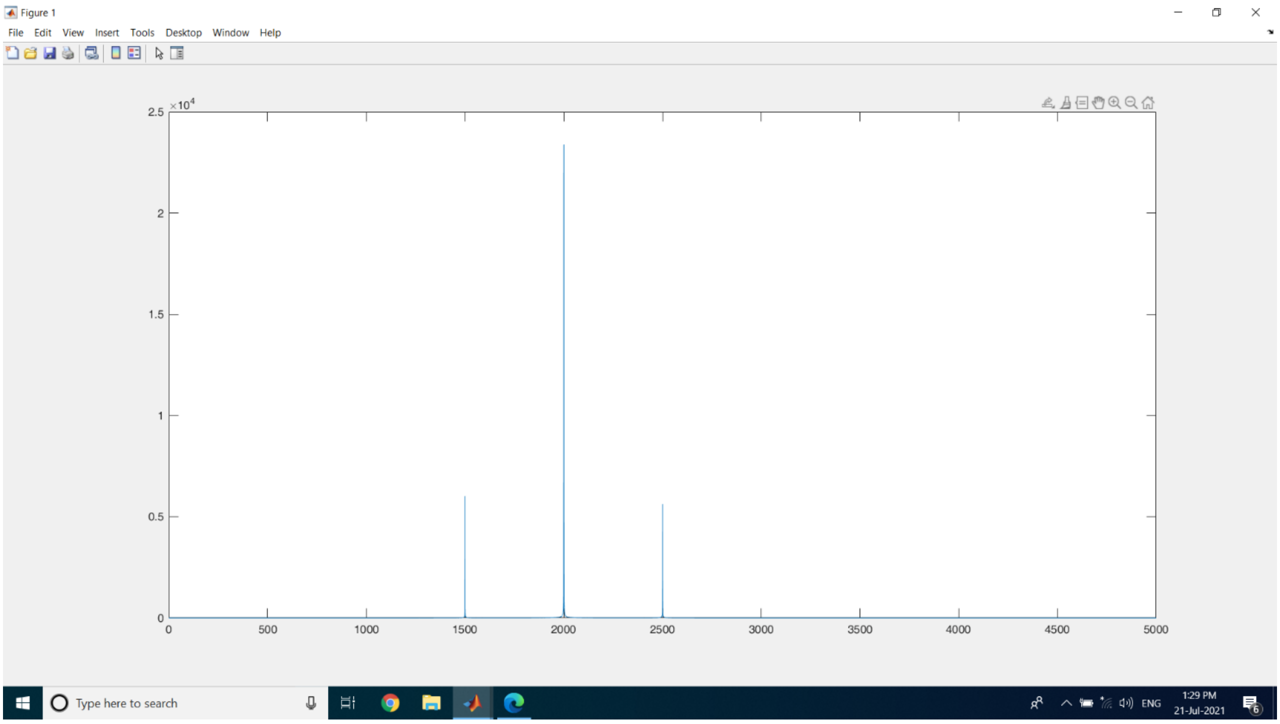

Figure 2 – spectrum of modulated signal

Case 2

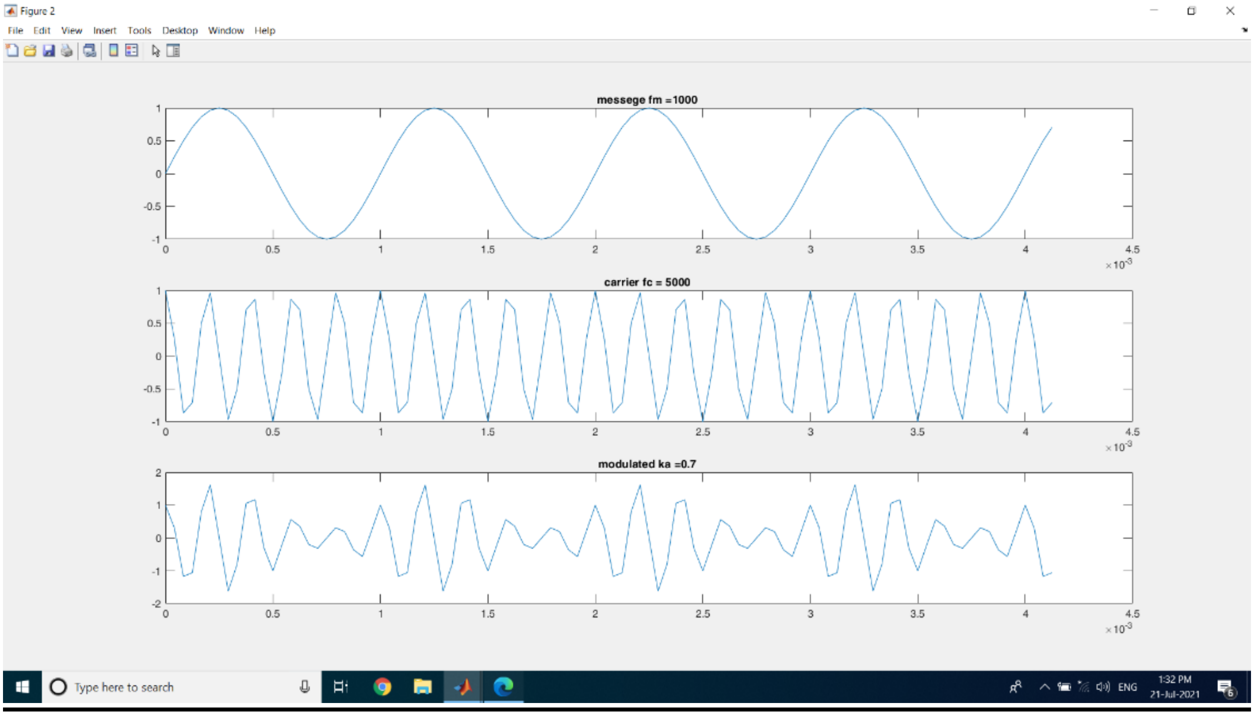

Figure 3 – Plot of the signal 2

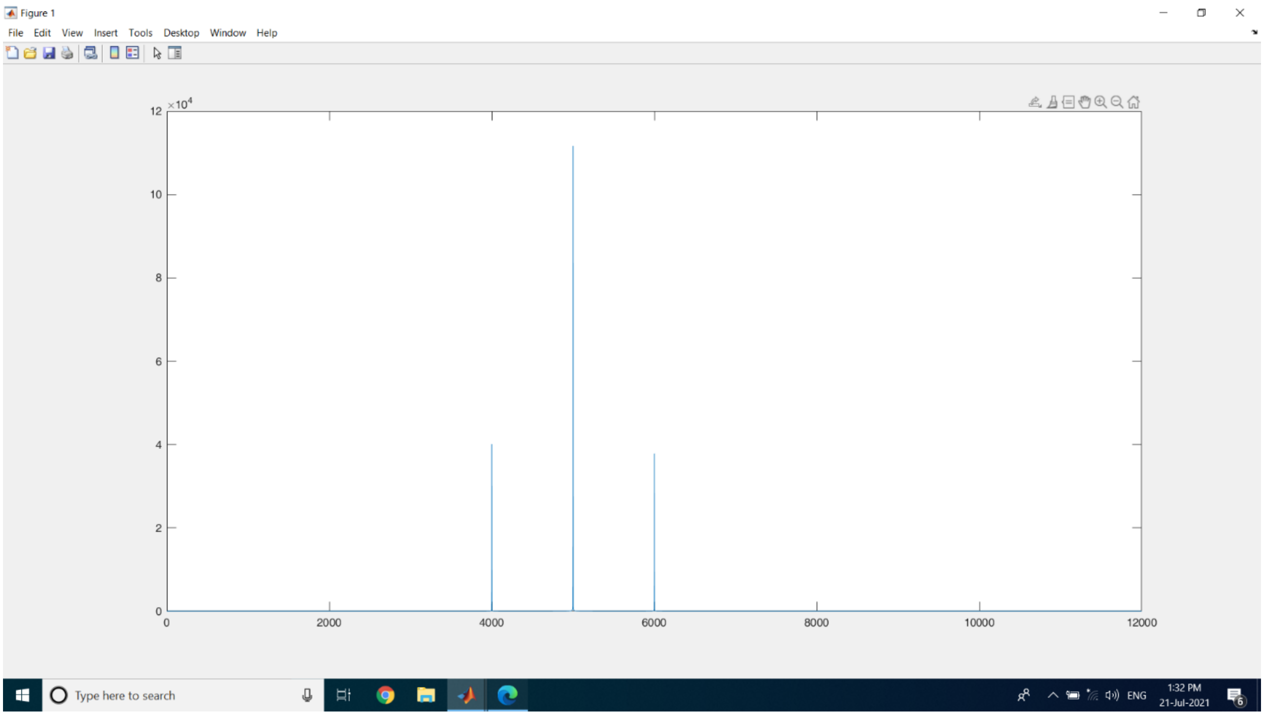

Figure 4 – Spectrum of the modulated signal 2

Case 3

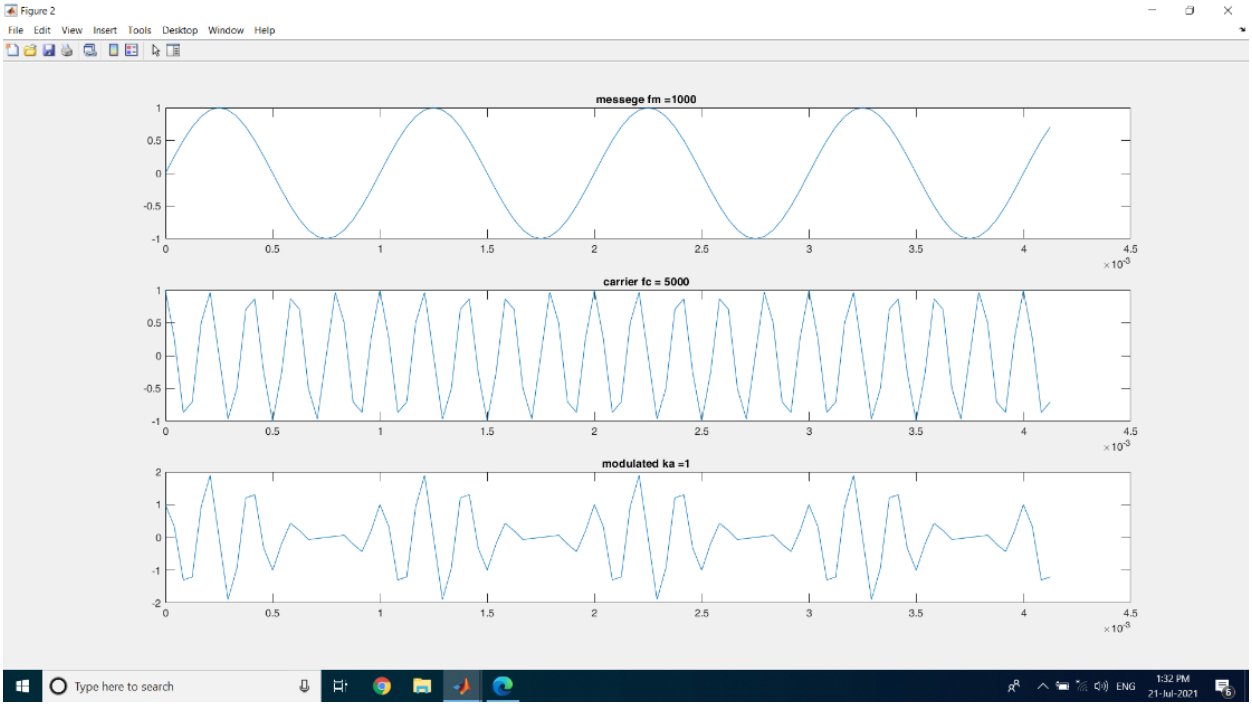

Figure 5 – Plot of the signal 3

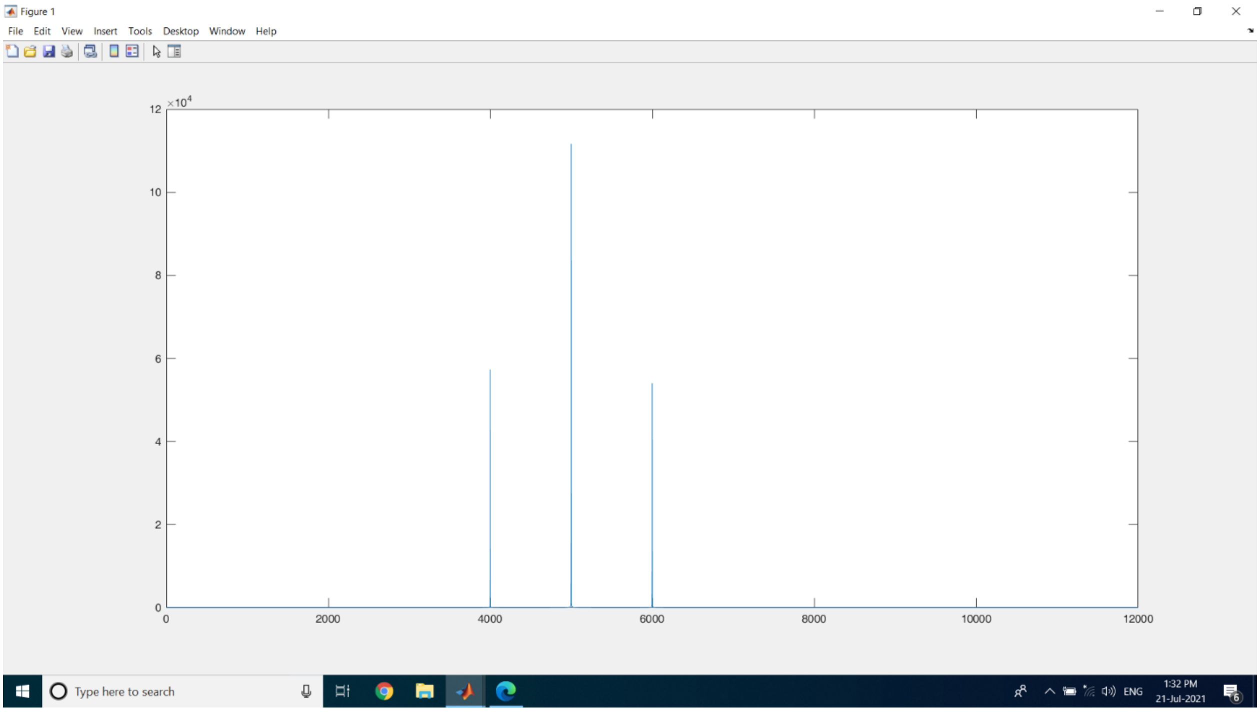

Figure 6 – Spectrum of the modulated signal 2

AM Demodulation

Finding correct parameter for the filter

By changing the transmission region width we can set stop and pass band frequencies.

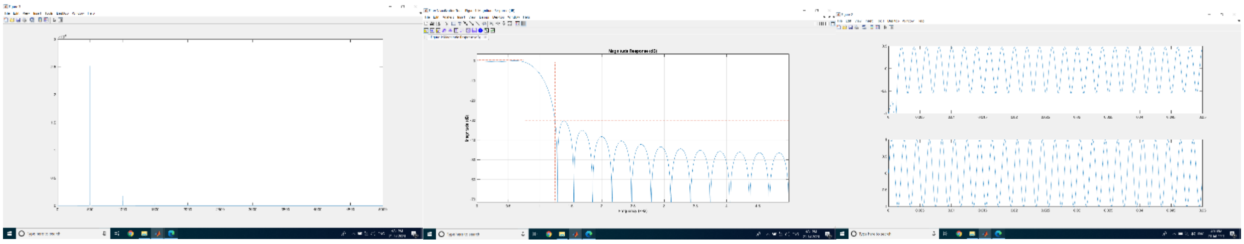

Figure 7 – higher transition width

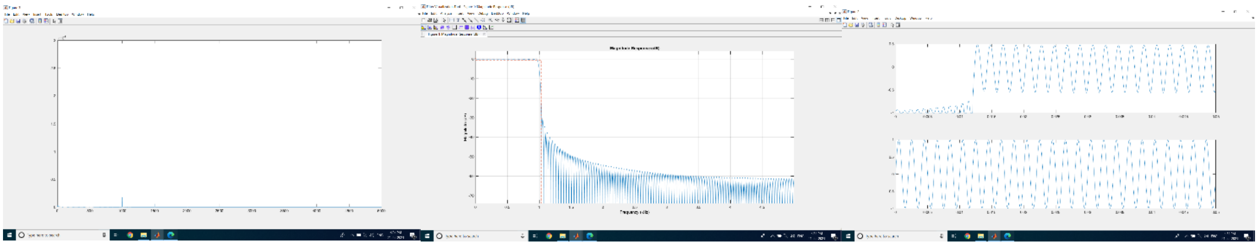

Figure 8 –medium transition width

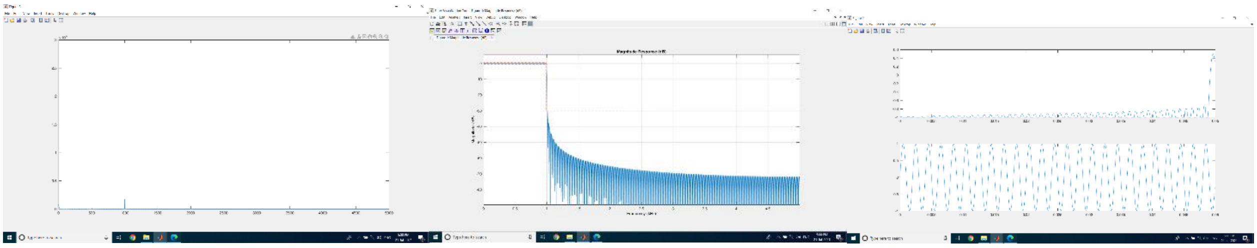

Figure 9– lower transition width

By observing the results we can choose a higher transition width for the filter since the demodulated signal and the message signal look alike.

Choosing the filter

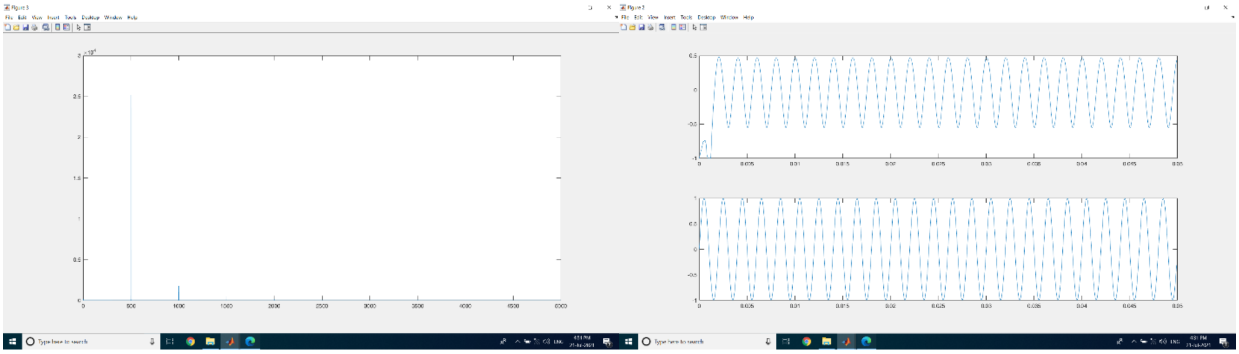

Figure 10 – Kaiser window

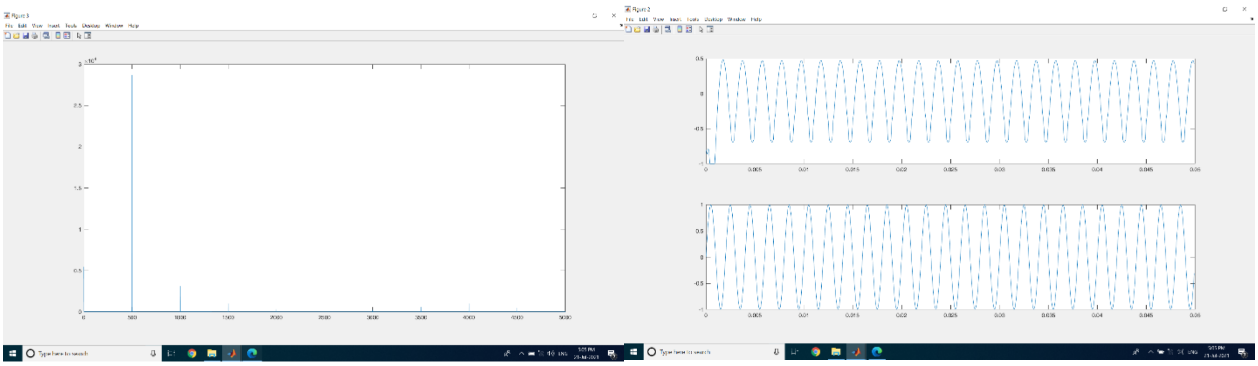

Figure 11 – equiripple

It is observable that Kaiser window has less unrelated frequency components. Reason for that is Kaiser window the stop band is attenuated gradually as in equiripple filter stop band ripple doesn't descend as the frequency goes to infinity.

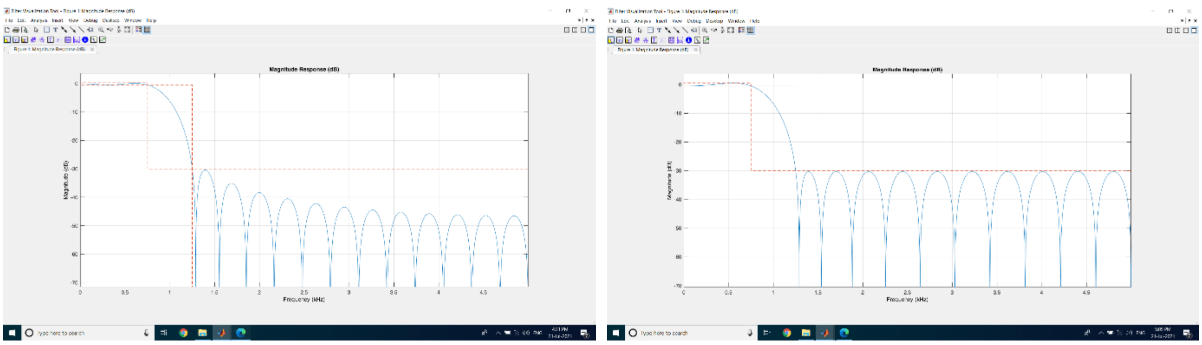

Figure 12 – Kaiser window filter vs equi ripple

Filter Parameters

Type	: Kaiser Window
Stop band frequency	: fm+(fc-2*fm)/2-(fc-2*fm)/4
Pass band frequency	: fm+(fc-2*fm)/2+(fc-2*fm)/4
Attenuation in the passband	: 1 db
Attenuation in the stopband	: 30 db

```
clear all;

ka=input('ka');
fm=input('fm');
fc=input('fc');
len=10;

t=0:1/(4*(fm+fc)):len;
m=sin(2*pi*fm*t);
c=cos(2*pi*fc*t);
s=(1+ka*m).*c;

%square law demodulator
squared =s.*s;

%filter
order_par=4;
Fpass = fm+(fc-2*fm)/2-(fc-2*fm)/order_par;
Fstop = fm+(fc-2*fm)/2+(fc-2*fm)/order_par;
Ap = 1;
Ast = 30;
Fs = 4*(fm+fc);
type = 'kaiserwindow';
d =
designfilt('lowpassfir','PassbandFrequency',Fpass,'StopbandF
requency',Fstop,'PassbandRipple',Ap,'StopbandAttenuation',As
t,'SampleRate',Fs,'DesignMethod',type);

hfvt = fvtool(d);
filt_data=filter(d,squared);
demod_m=sqrt(2*filt_data)-1;

f1=figure;
f2=figure;

figure(f1);
subplot(2,1,1);
plot(t(1:500),demod_m(1:500))

subplot(2,1,2);
```

```
plot(t(1:500),m(1:500))

figure(f2);
%fourier of modulatedd signal s
y=abs(fft(demod_m));

%matching lengths of f and y
f=0:1/len:2*(fc+fm);
p=y(1:2*(fc+fm)*len+1);
plot(f,p);
```

Message signal and the demodulated signal

Case 1

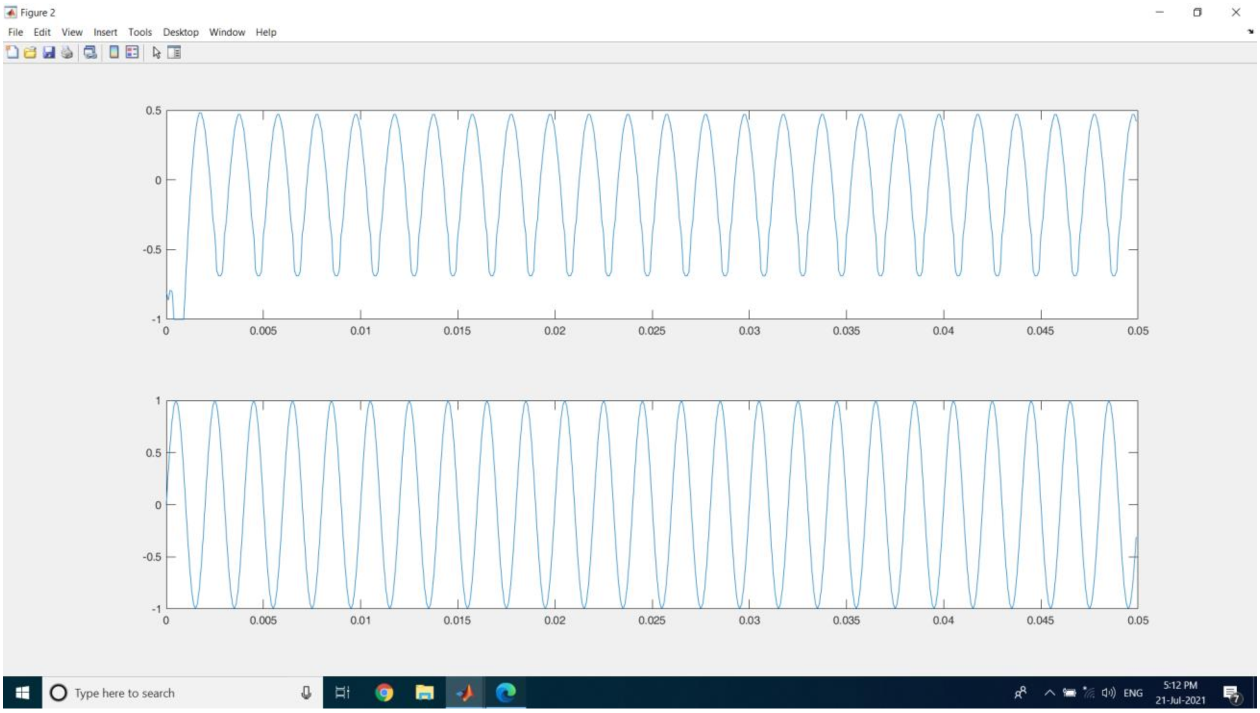

Figure 13 – top: demodulated signal 1, bottom : message signal 1

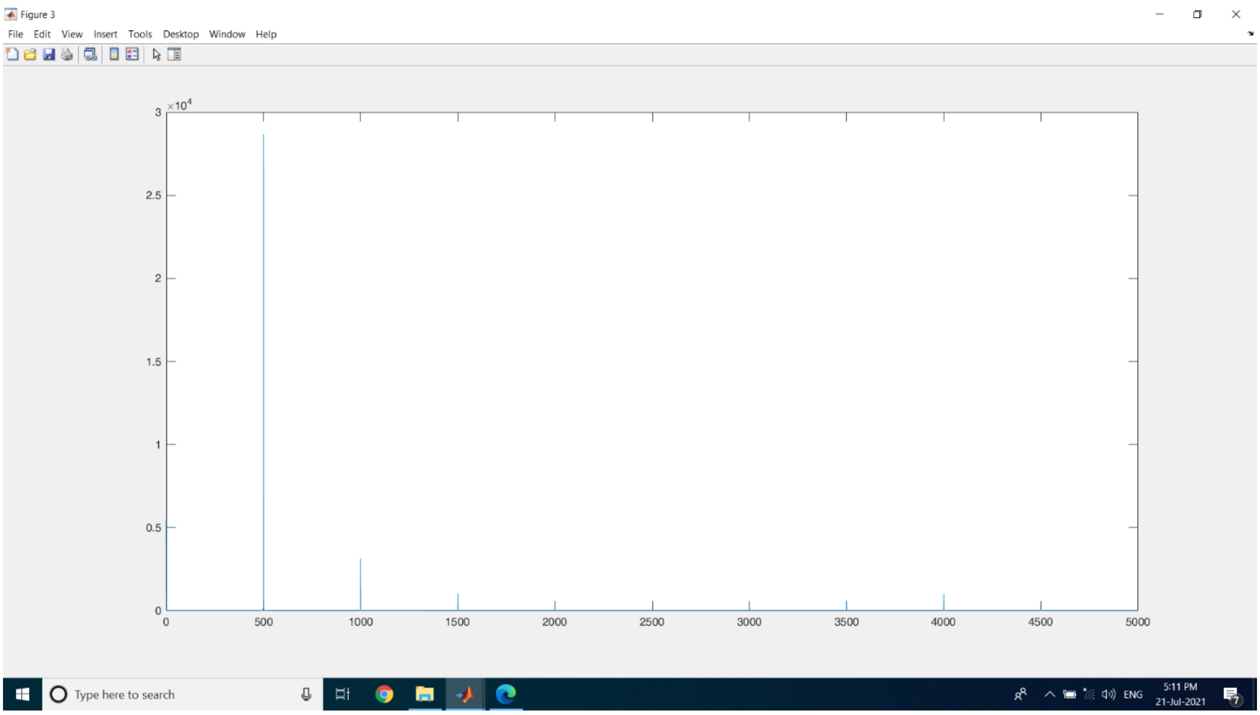

Figure 14 – spectrum of demodulated signal 1

Case 2

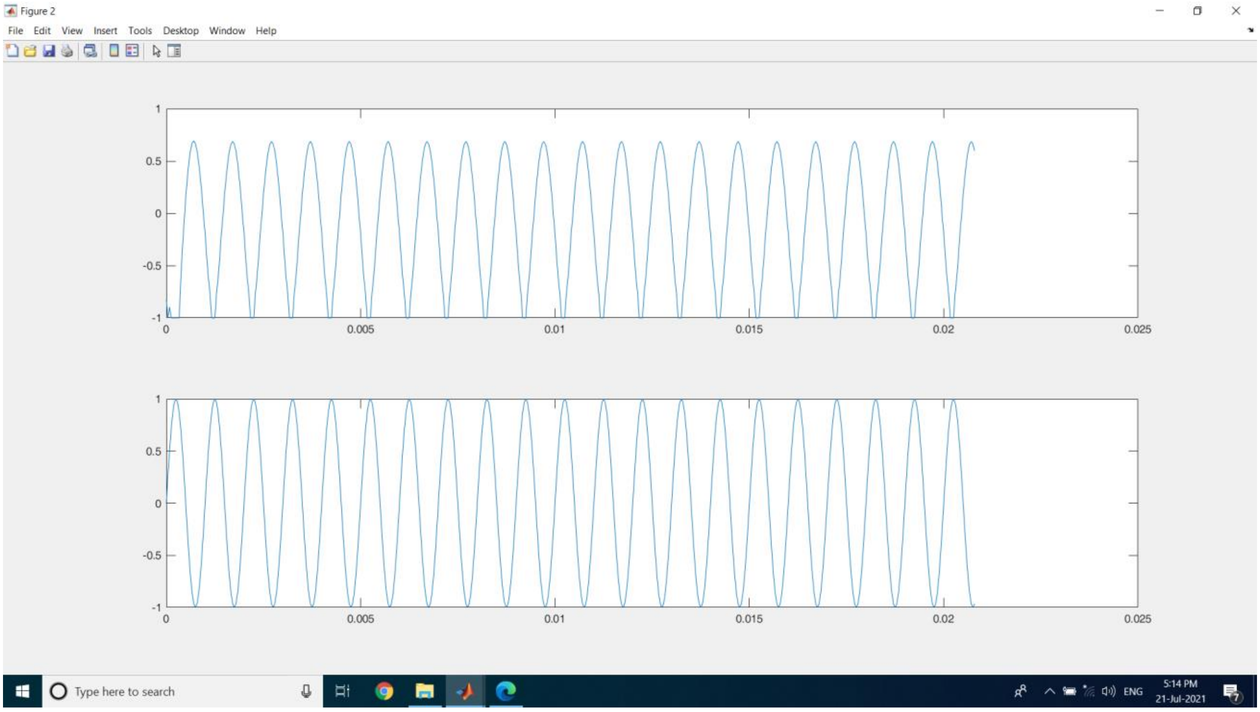

Figure 15 – top: demodulated signal 2, bottom : message signal 2

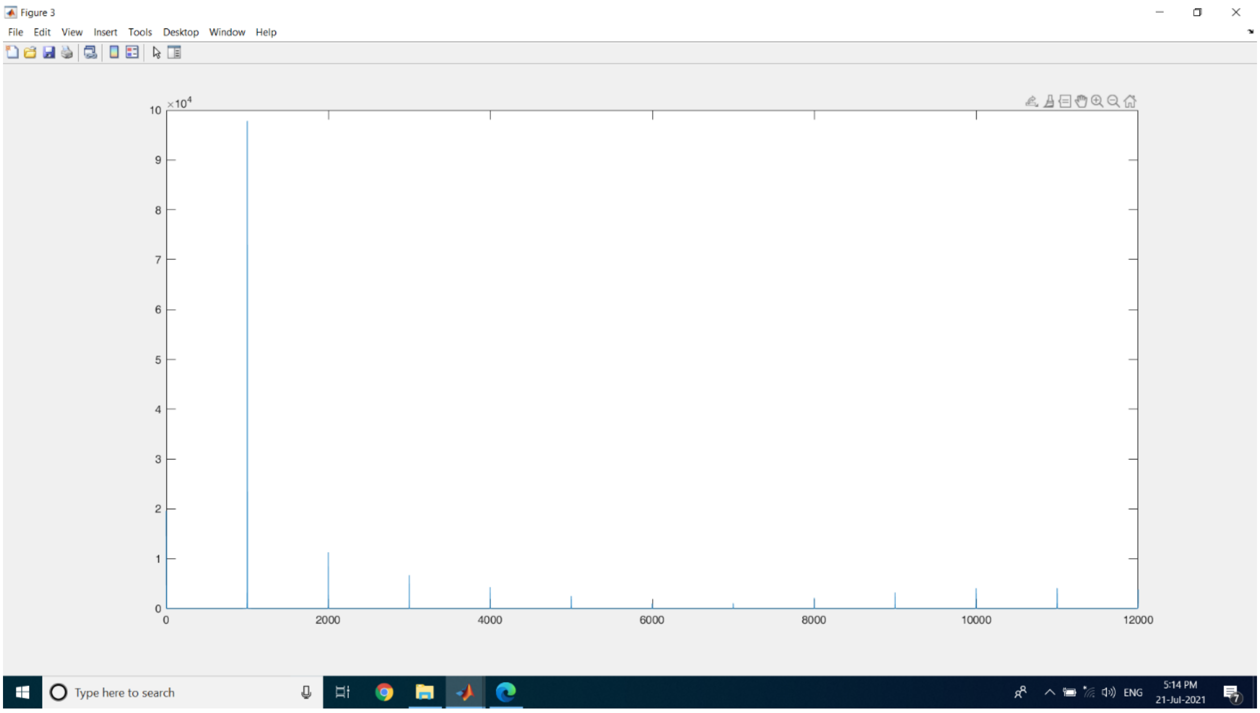

Figure 16 – spectrum of demodulated signal 2

Case 3

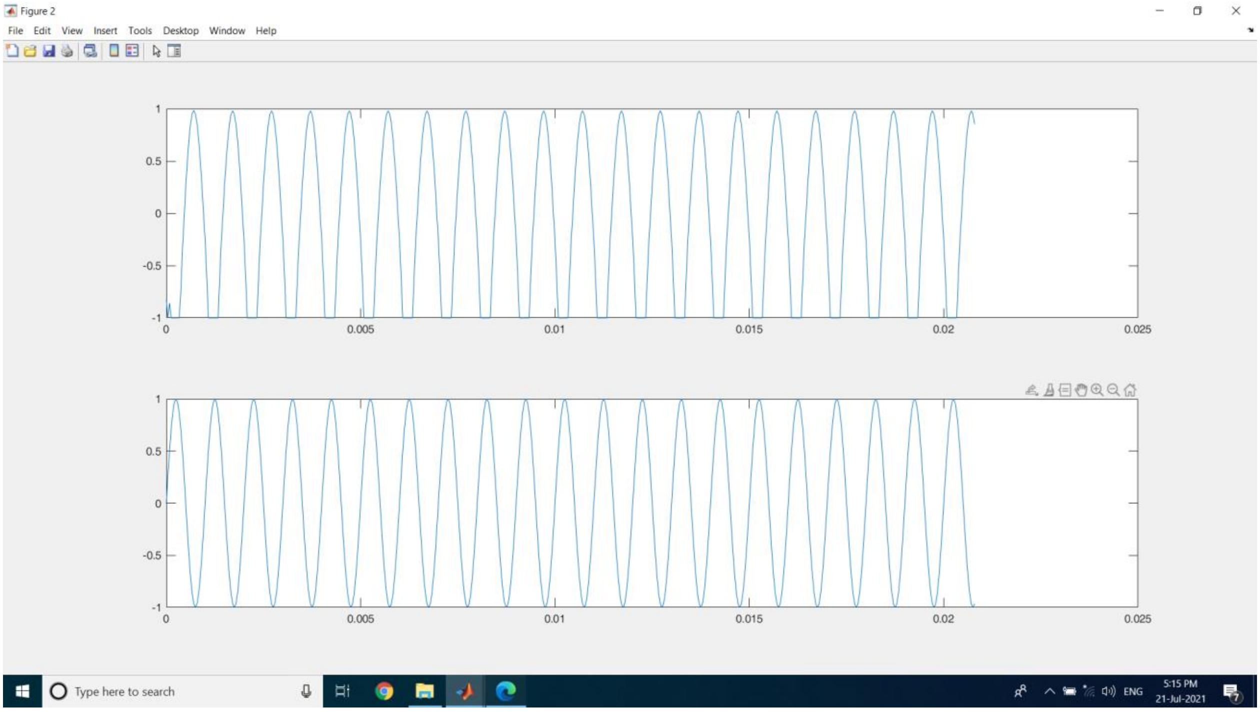

Figure 17 – top: demodulated signal 3, bottom : message signal 3

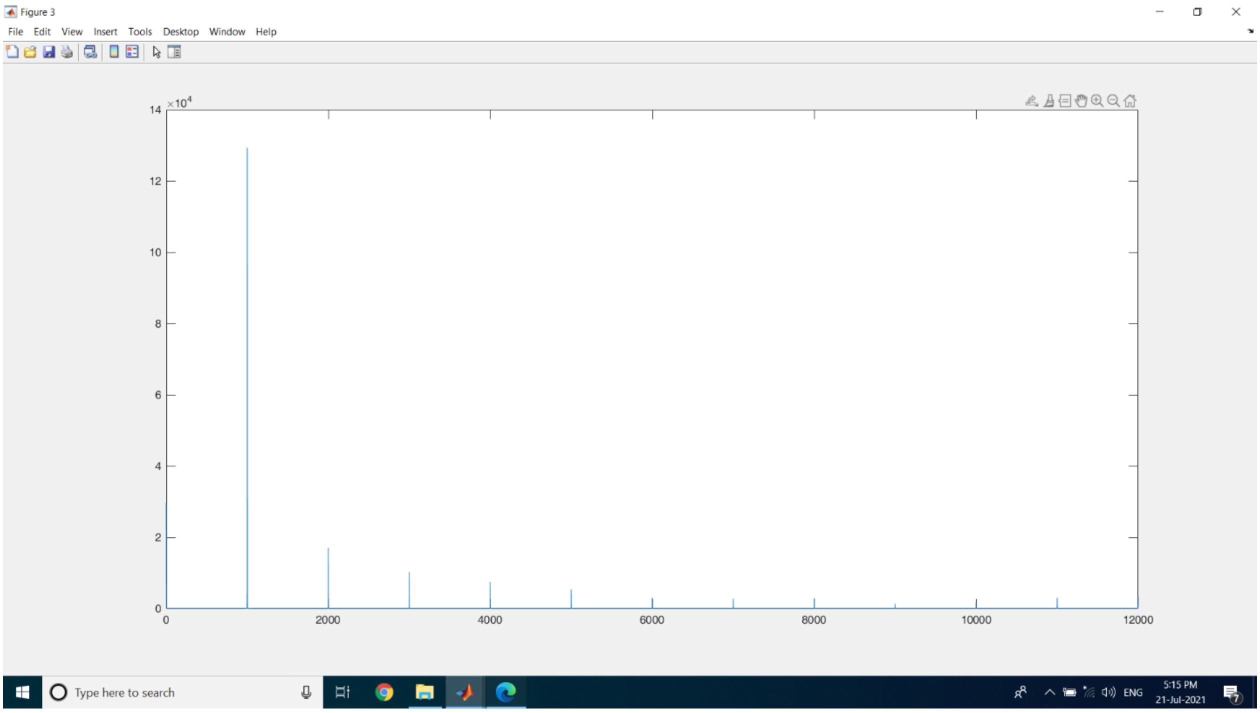

Figure 18 – spectrum of demodulated signal 3

What happens if passbands and stopbands are selected incorrectly?

Pass band frequency < Stop band frequency < Max frequency of message signal 1

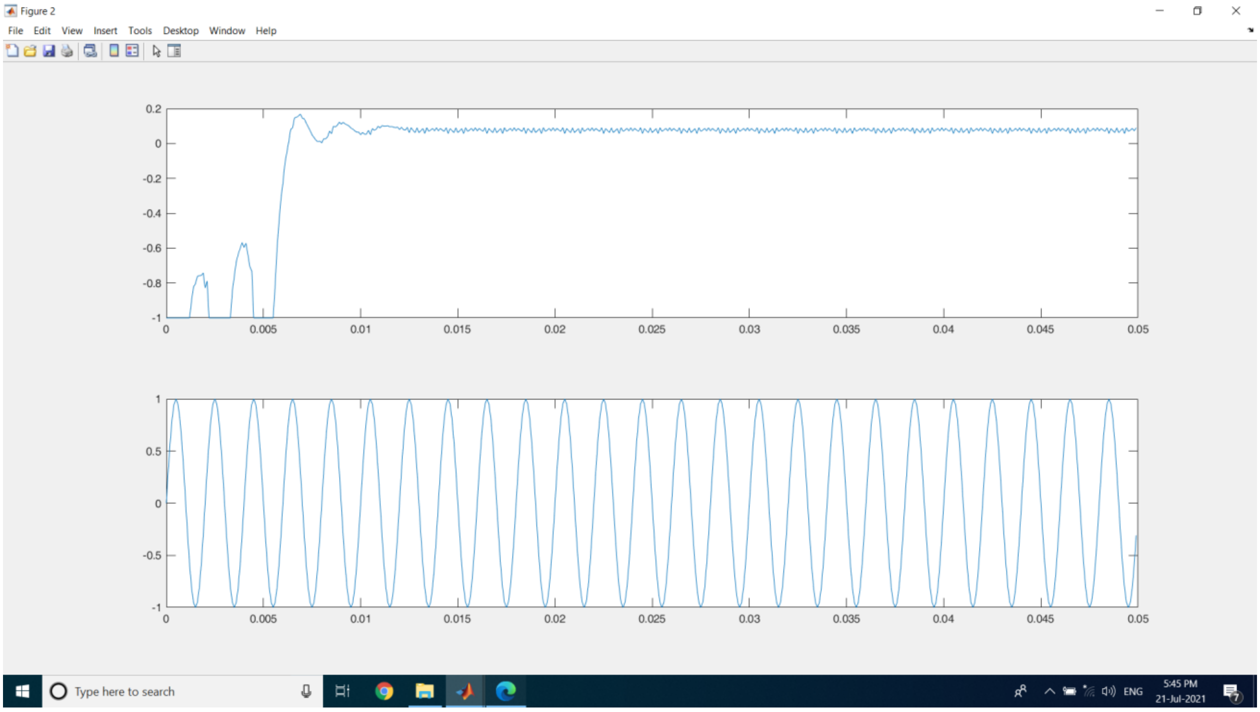

Figure 19 – top: filtered signal 1 with freq pass < freq stop < freq message, bottom : message signal 1

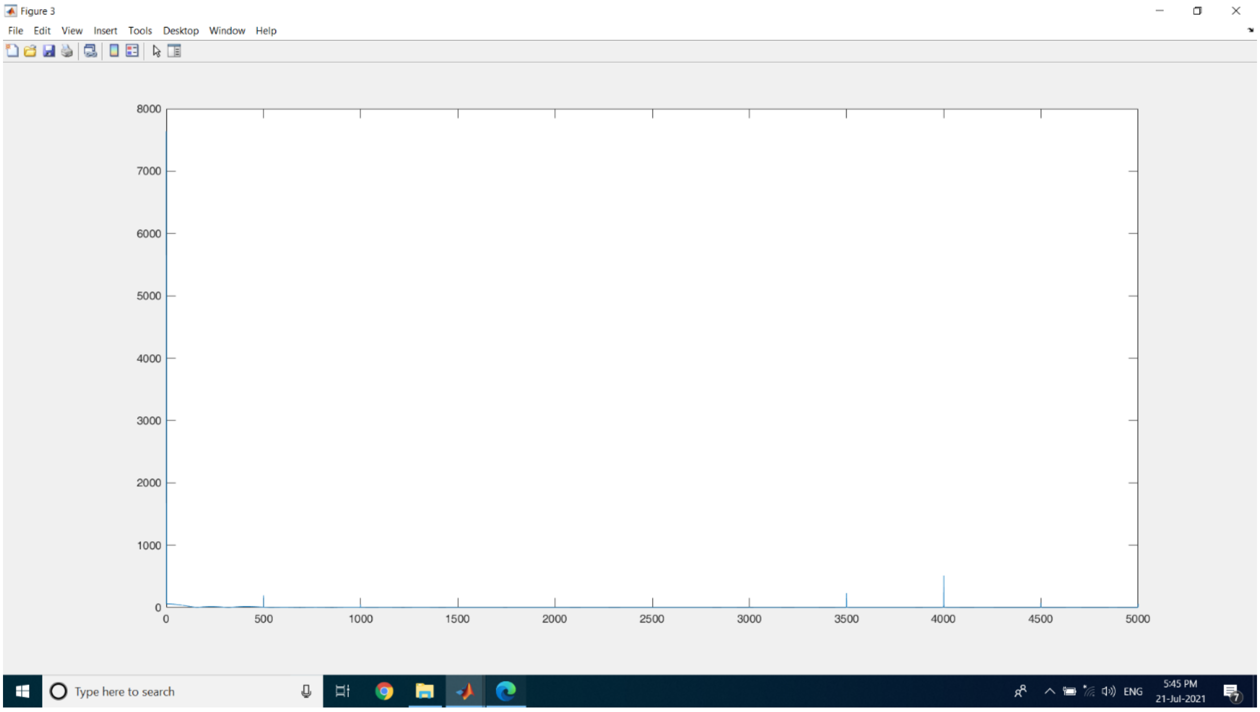

Figure 20 – spectrum of demodulated signal 1 with freq pass < freq stop < freq message filter settings

Pass band frequency < Stop band frequency < Max frequency of message signal 2

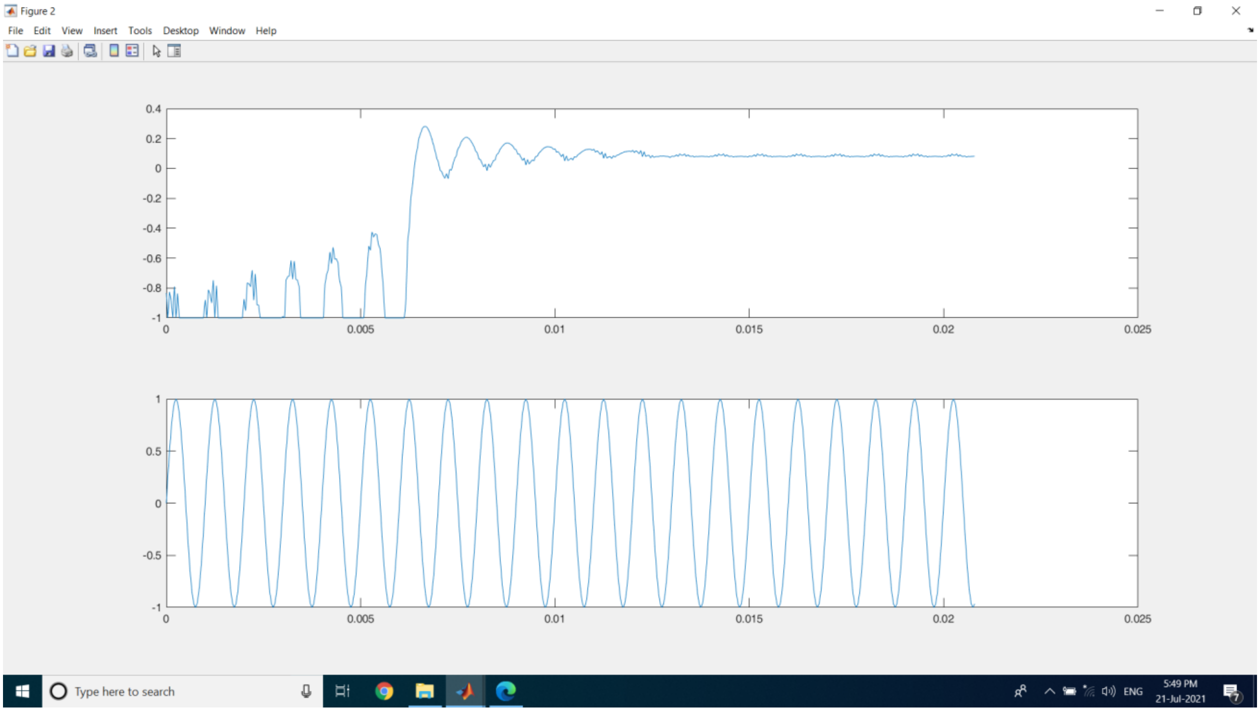

Figure 21 – top: filtered signal 2 with freq pass < freq stop < freq message, bottom : message signal 2

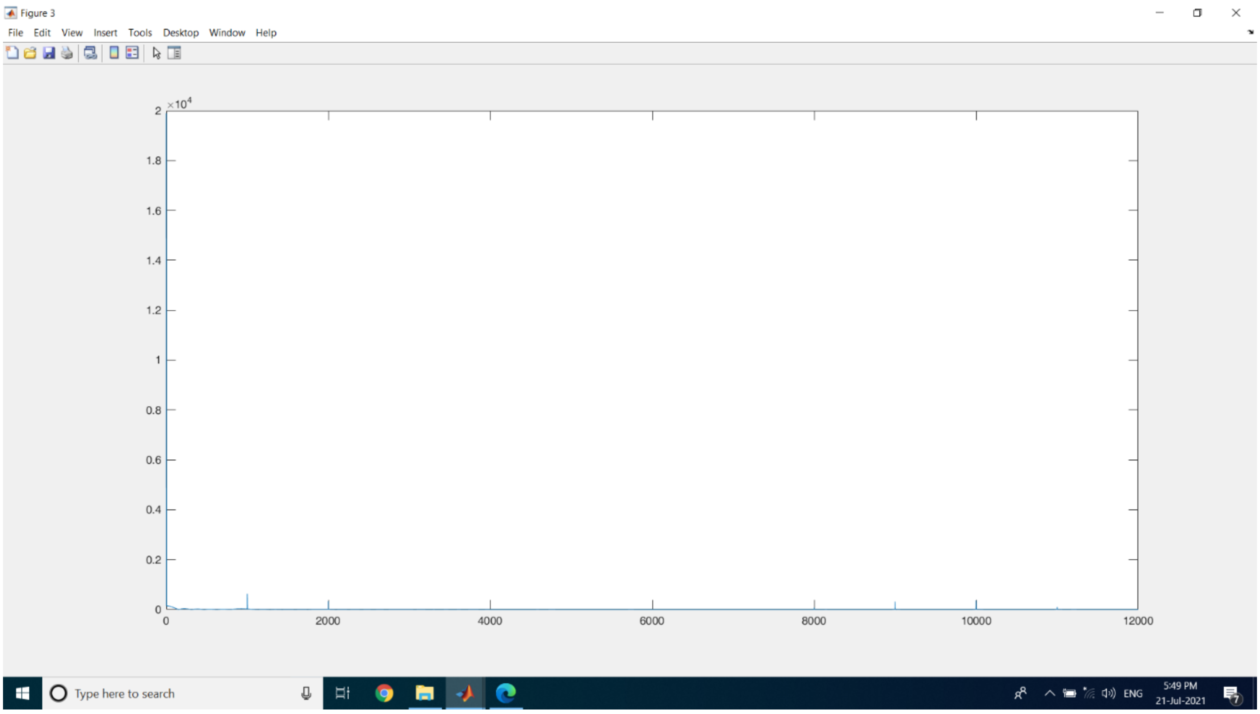

Figure 22 – spectrum of demodulated signal 2 with freq pass < freq stop < freq message filter settings

Pass band frequency < Stop band frequency < Max frequency of message signal 3

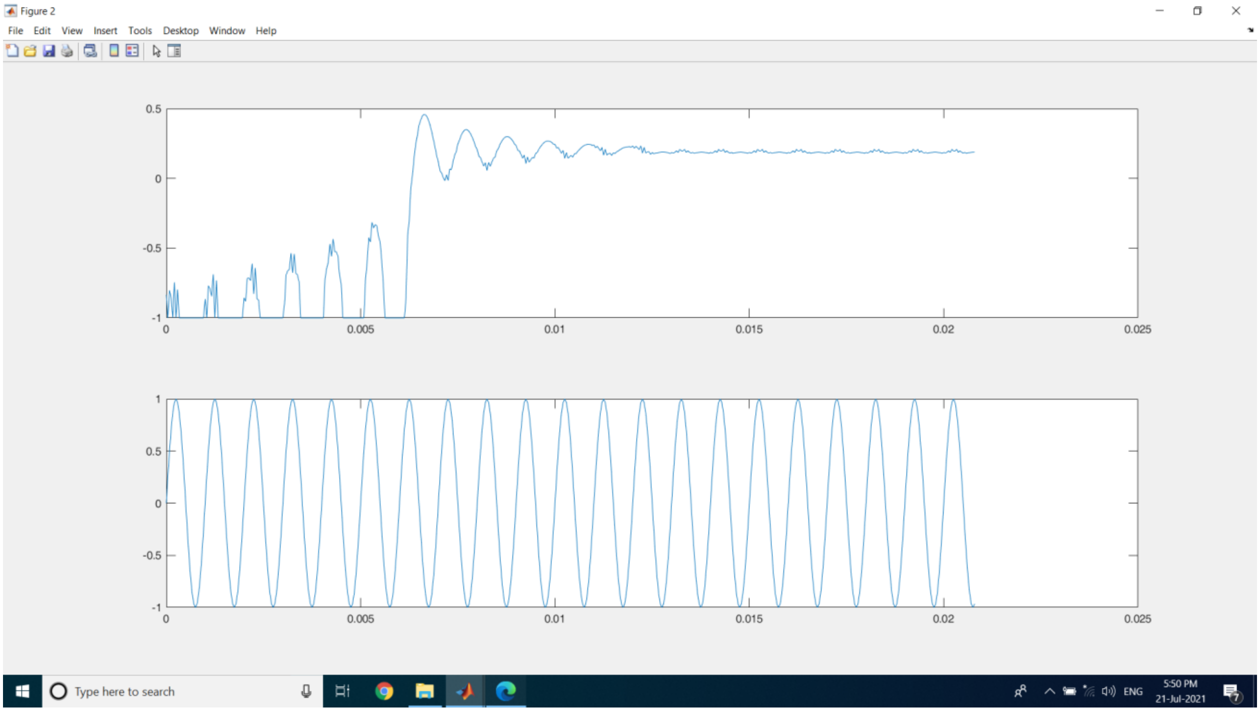

Figure 23 – top: filtered signal 3 with freq pass < freq stop < freq message, bottom : message signal 3

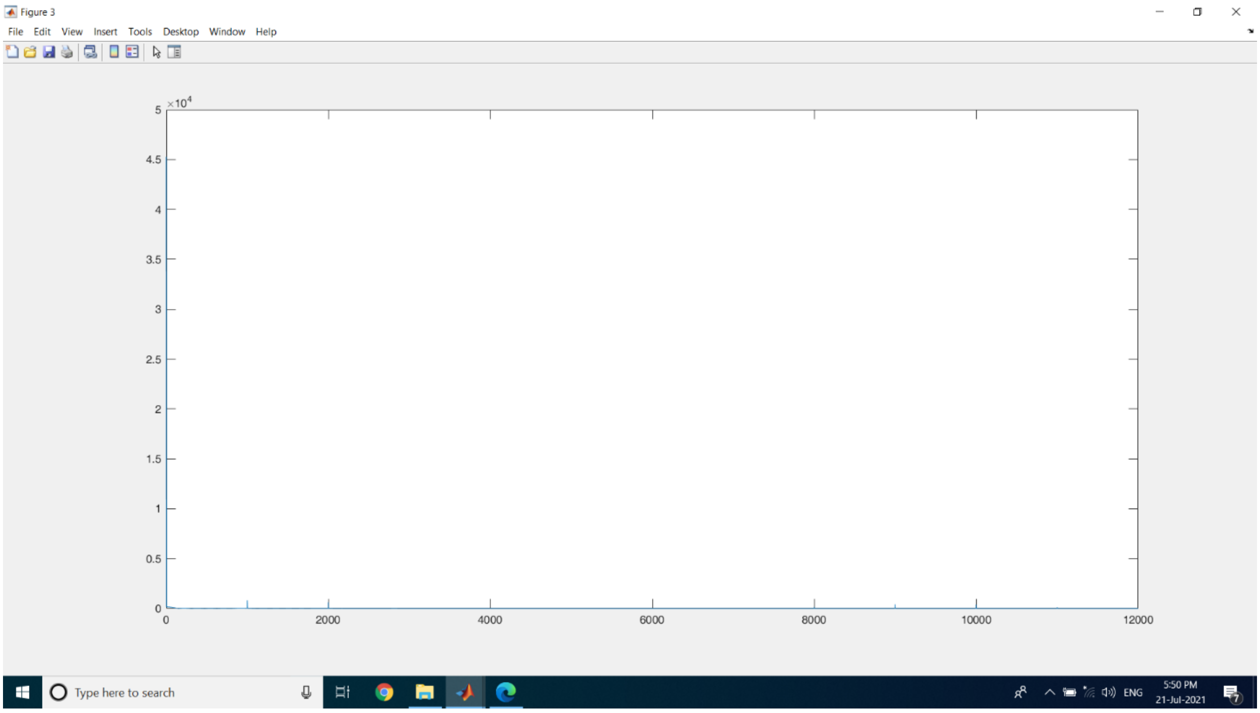

Figure 24 – spectrum of demodulated signal 3 with freq pass < freq stop < freq message filter setting

Pass band frequency < Max frequency of message signal 1< Stop band frequency

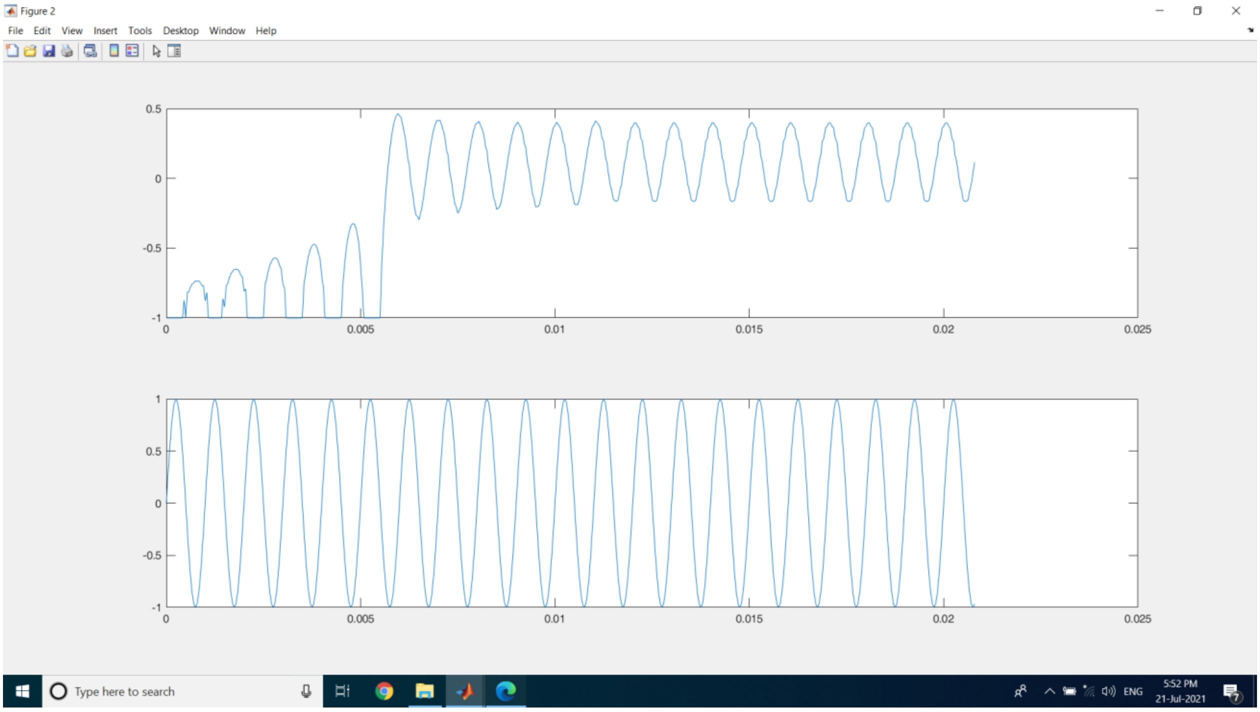

Figure 25 – top: filtered signal 1 with freq pass < freq message < freq stop, bottom : message signal 1

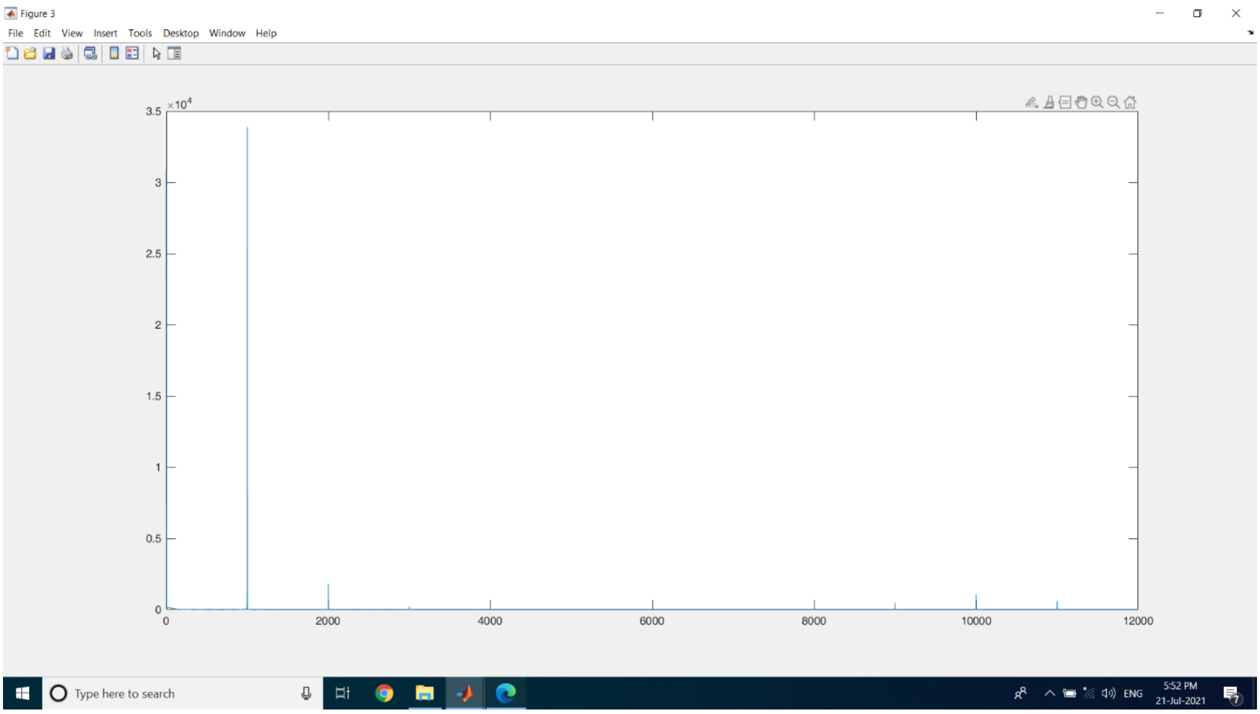

Figure 26 – spectrum of demodulated signal 1 with freq pass < freq message < freq stop filter settings

Pass band frequency < Max frequency of message signal 2< Stop band frequency

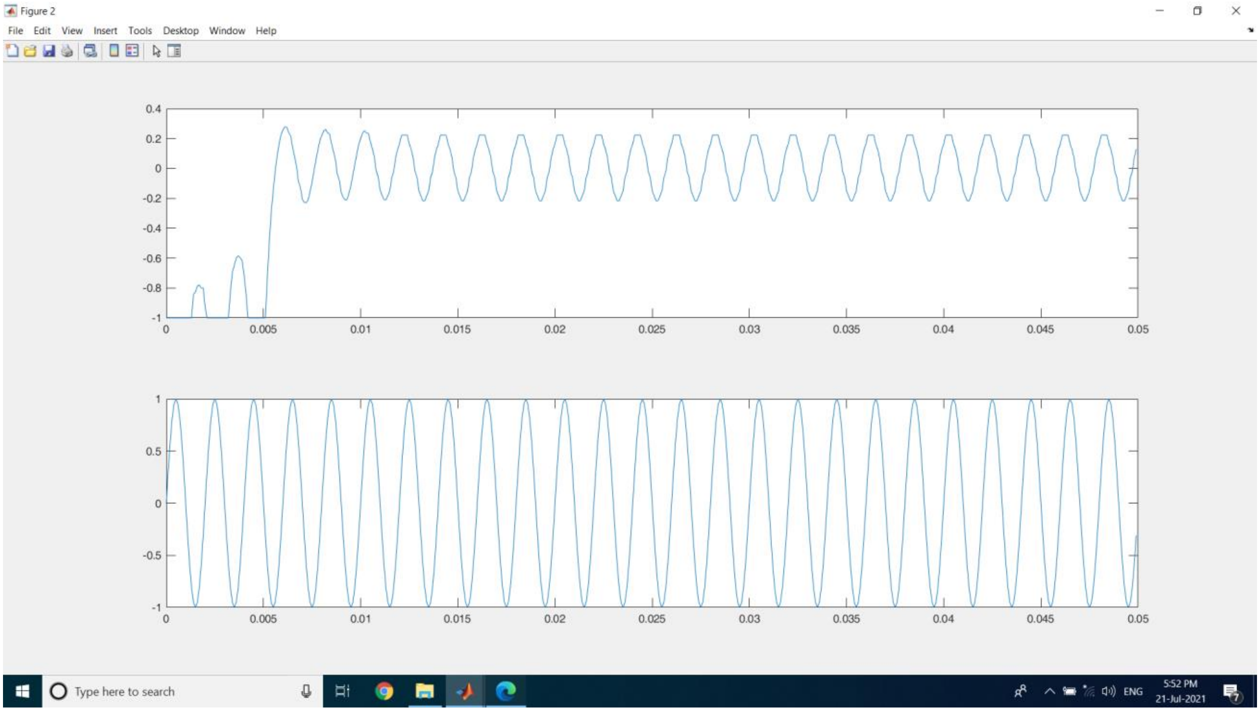

Figure 27 – top: filtered signal 2 with freq pass < freq message < freq stop, bottom : message signal 2

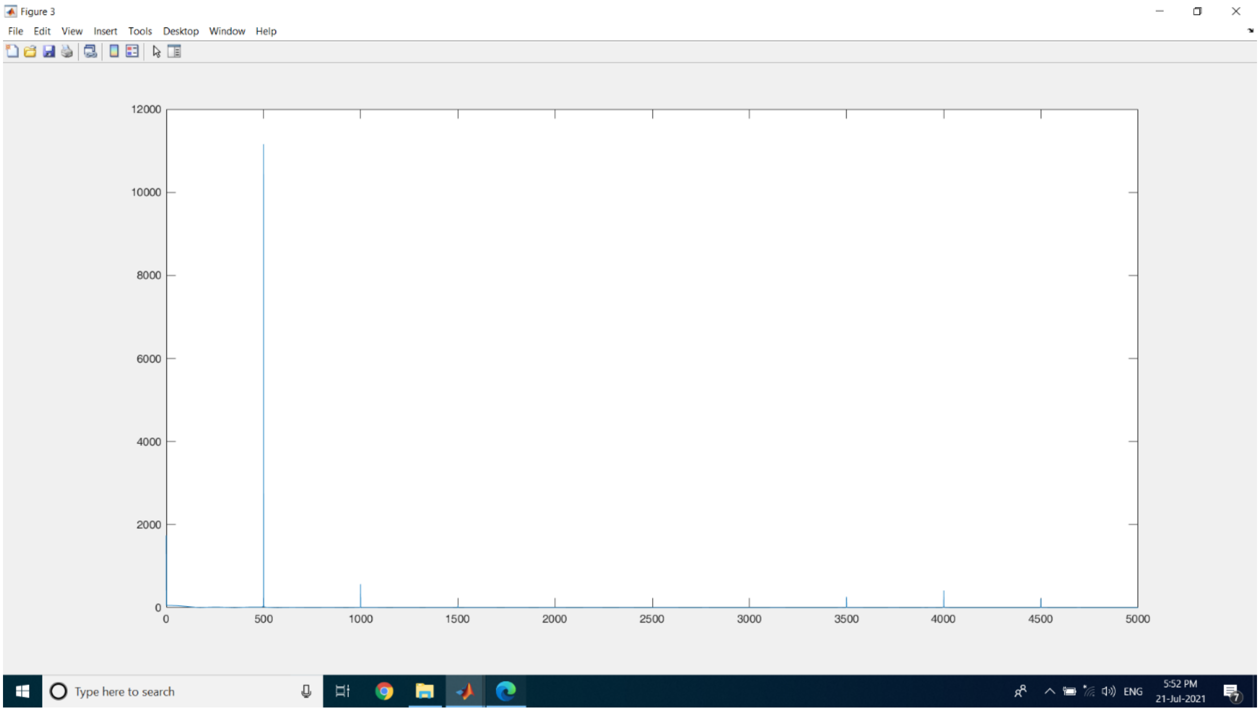

Figure 28 – spectrum of demodulated signal 2 with freq pass < freq message < freq stop filter settings

Pass band frequency < Max frequency of message signal 3< Stop band frequency

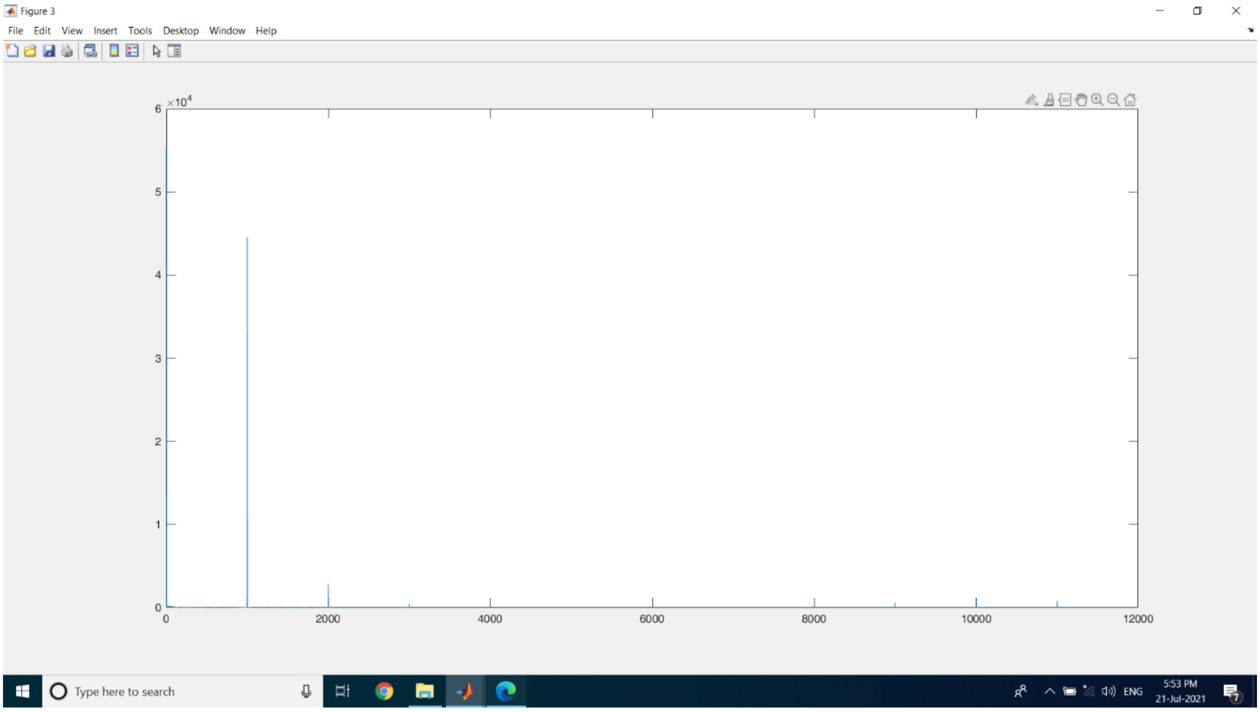

Figure 29 – top: filtered signal 3 with freq pass < freq message < freq stop, bottom : message signal 3

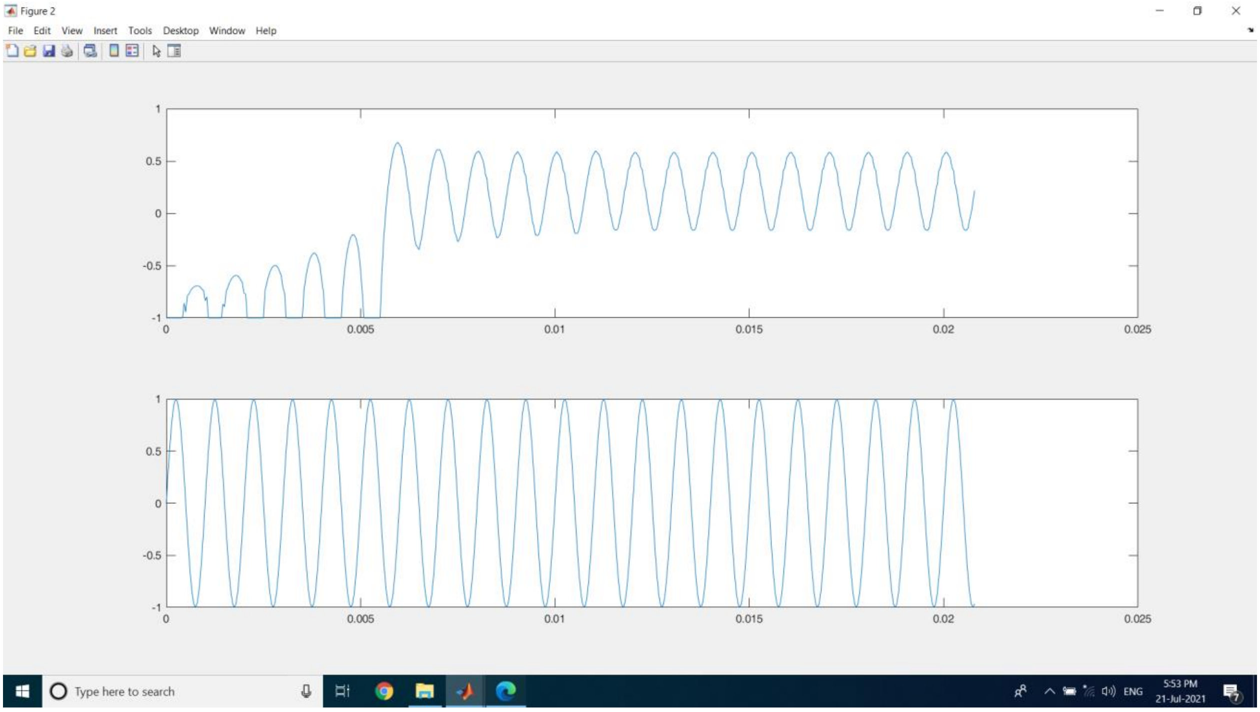

Figure 30 – spectrum of demodulated signal 3 with freq pass < freq message < freq stop filter settings

Max frequency of message signal 1 < Pass band frequency < Stop band frequency

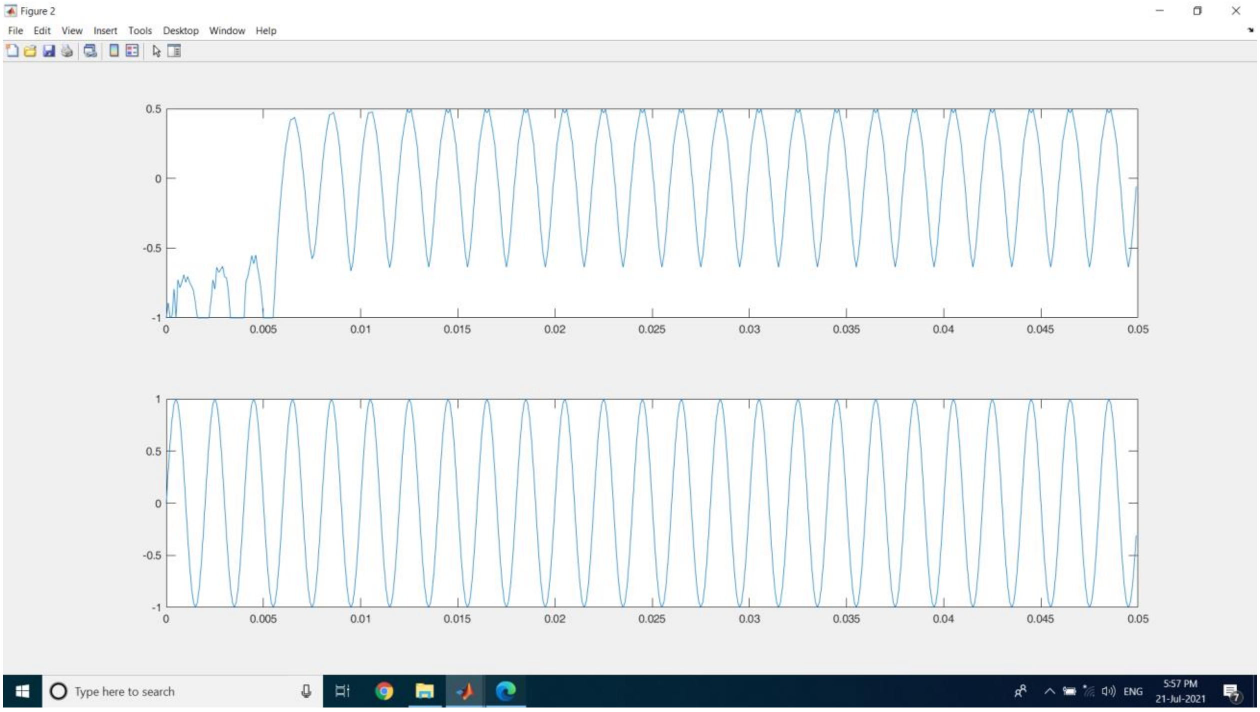

Figure 31 – top: filtered signal 1 with freq message< freq pass < freq stop, bottom : message signal 1

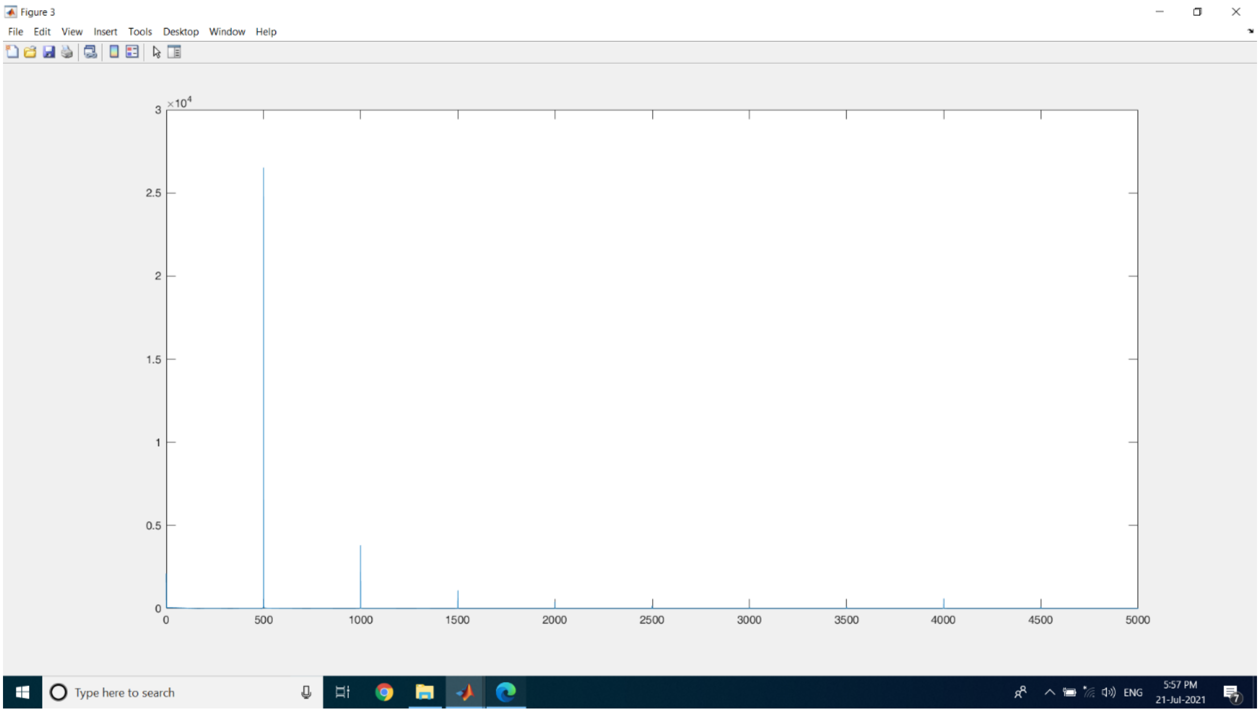

Figure 32 – spectrum of demodulated signal 1 with freq message< freq pass < freq stop filter settings

Max frequency of message signal 2 < Pass band frequency < Stop band frequency

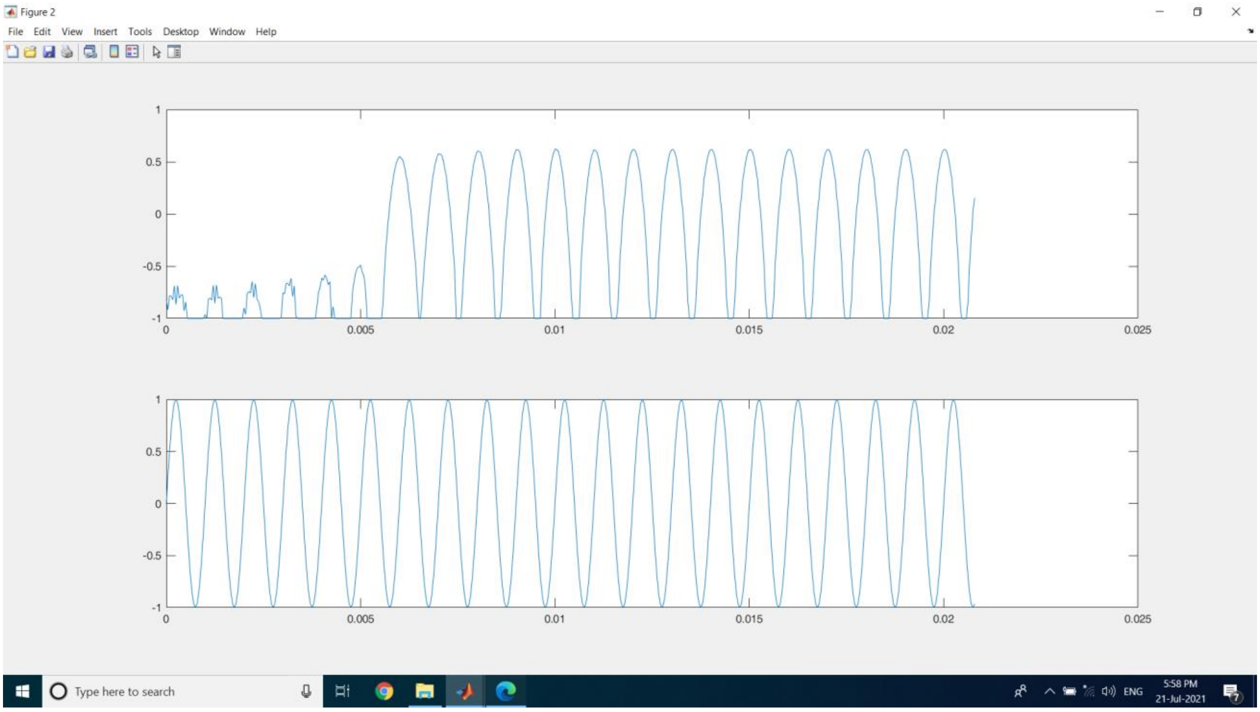

Figure 33 – top: filtered signal 2 with freq message< freq pass < freq stop, bottom : message signal 2

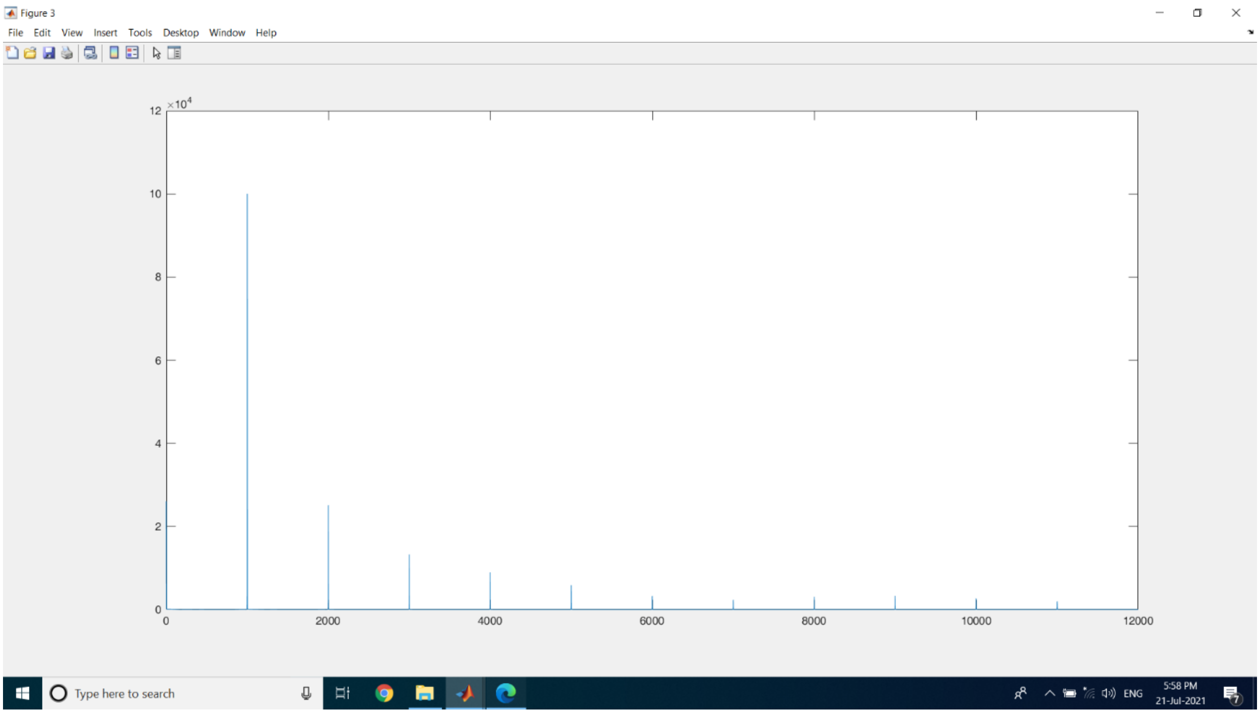

Figure 34 – spectrum of demodulated signal 2 with freq message< freq pass < freq stop filter setting

Max frequency of message signal 3 < Pass band frequency < Stop band frequency

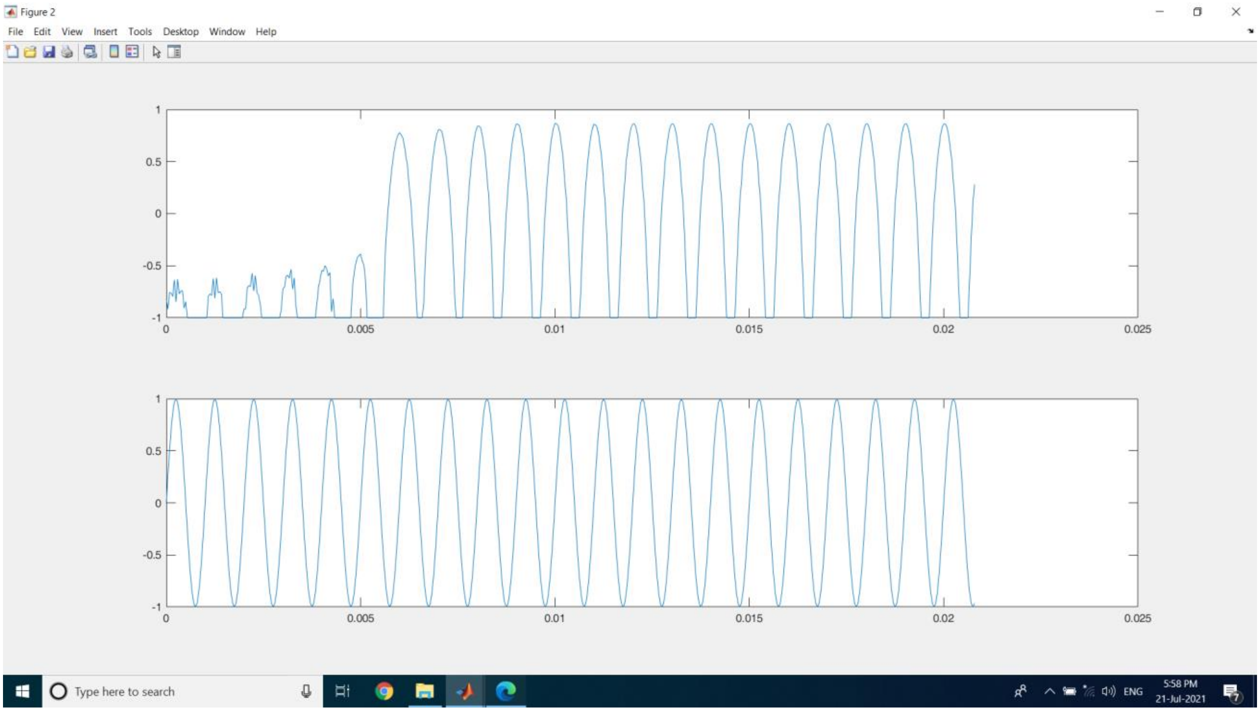

Figure 35 – top: filtered signal 3 with freq message< freq pass < freq stop, bottom : message signal 3

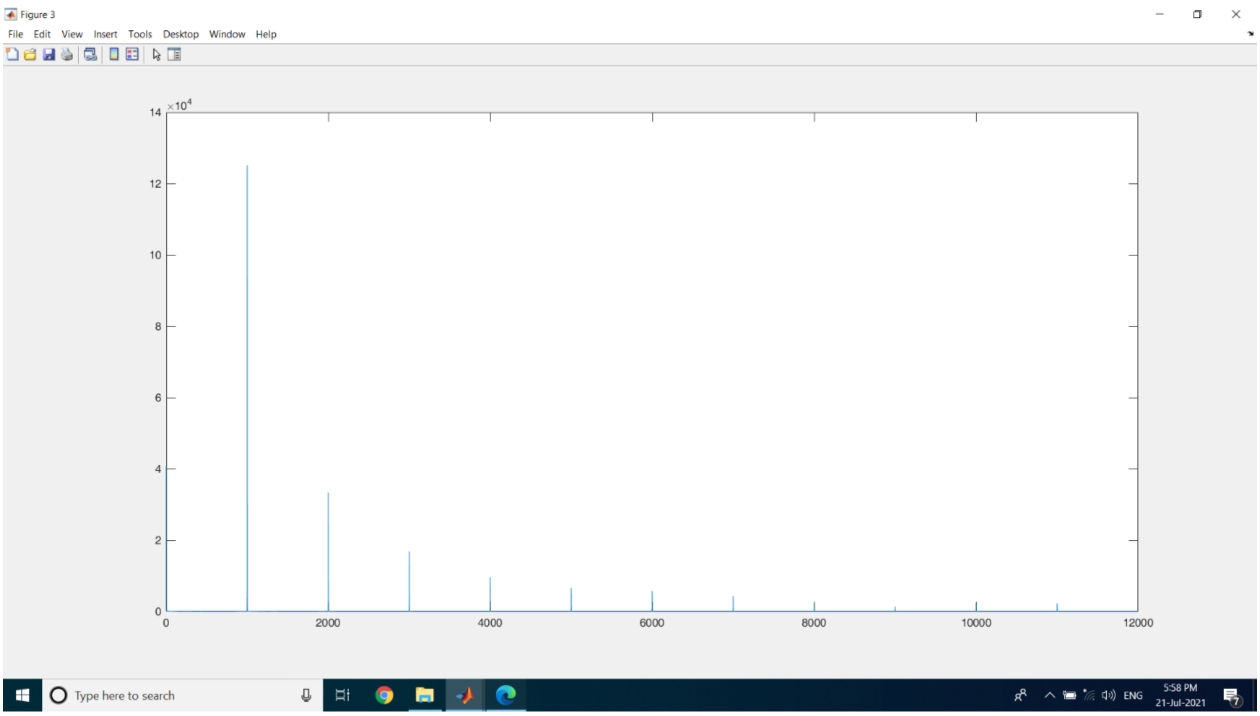

Figure 36 – spectrum of demodulated signal 3 with freq message< freq pass < freq stop filter settings

Conclusion is that choosing the wrong filter setting generate undesirable frequencies due to aliasing and the demodulated message signal will become ore unlikely to the original message signal.

a). To avoid including unwanted frequencies we should choose stop and pass bands correctly. When a signal is sampled in Fs if we observe frequency spectrum the message signal is repeated around multiples of Fs frequencies due to the fact that multiplication in time domain is convolution in frequency domain. So the safe space we are left to choose our pass and stop band frequencies are in between maximum frequency of our message signal (fm) and Fs -fm.

What happens if the filter has too high/low bandwidth?

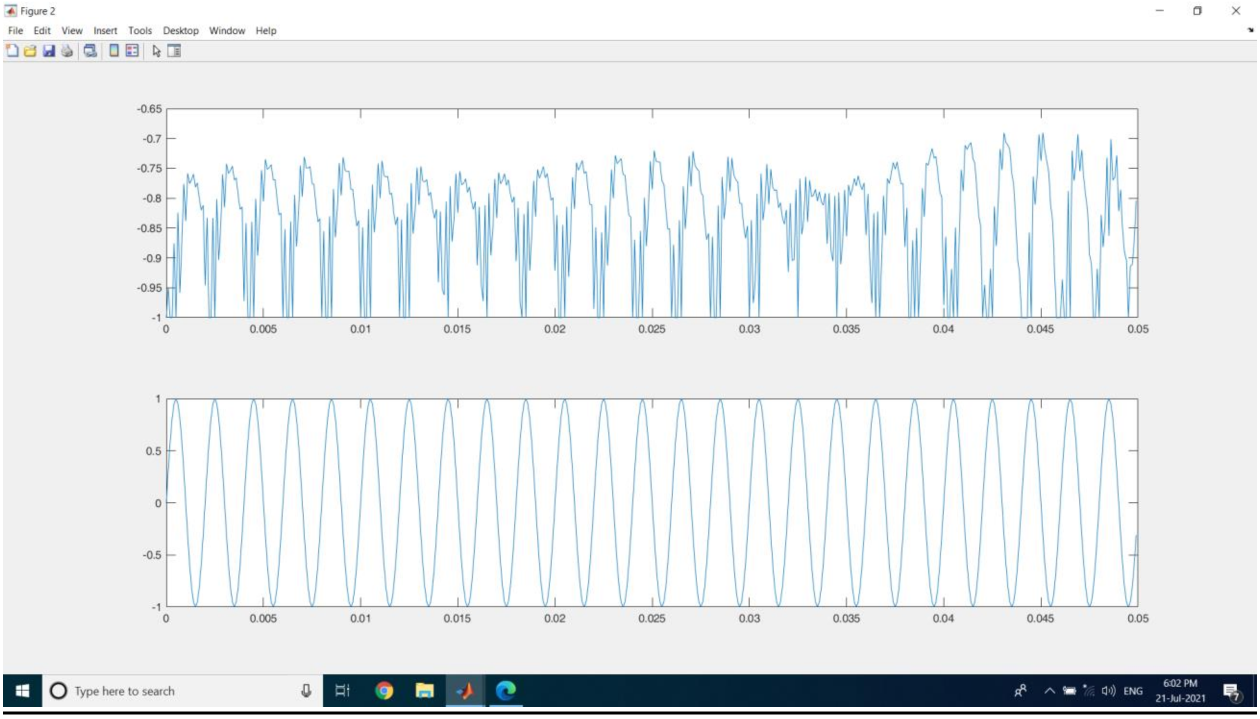

Figure 37 – filtered with low band width

Has a steep transition but have more ripples in the pass band

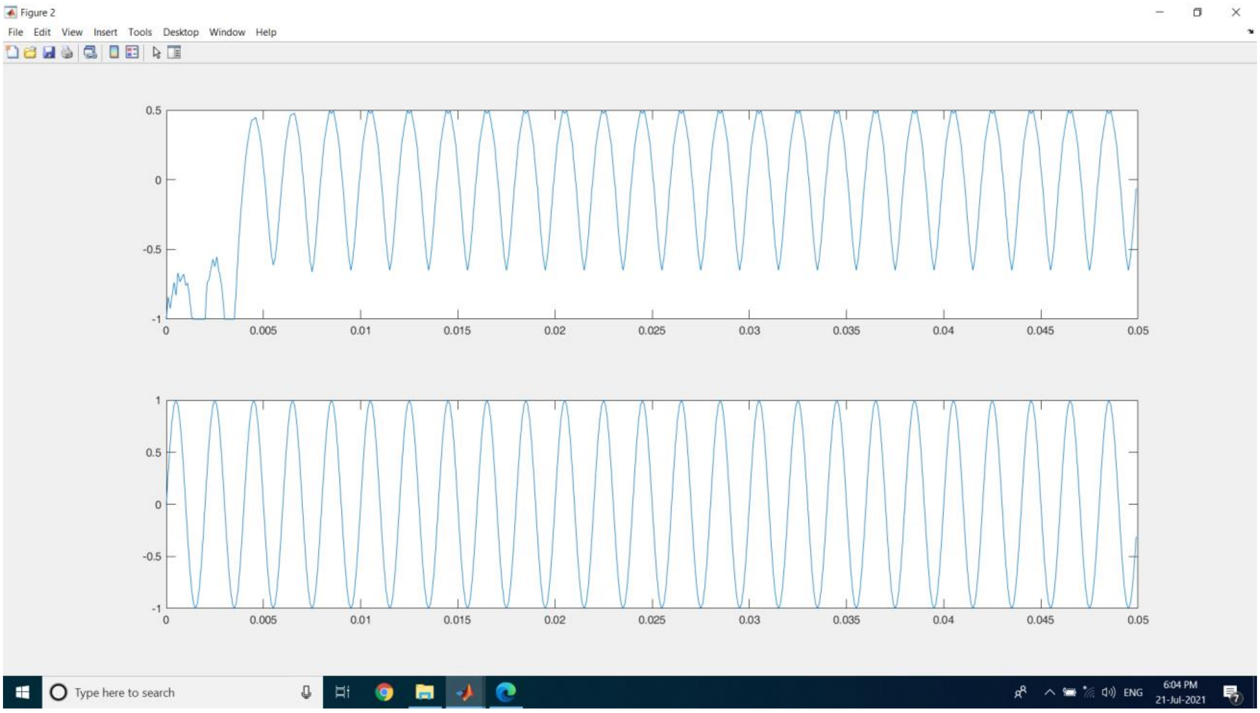

Figure 38 – filtered with high band width

flat in the pass band. Less noise. But having higher bandwidth may cause unwanted frequencies to appear in the final demodulated signal.

DSB-SC Modulation and Demodulation

Section I - Multiplier Modulator/Demodulator

```
fm=15000;
fc=250000;
t=0:1/(8*(fm+fc)):8;
m=.5*cos(2*pi*fm*t);
c=1.4*cos(2*pi*fc*t);
s=m.*c;

%demodulation

e=s.*c;
[b,a] = butter(5,2*pi* 2 * 15 * 1000/(8*(fm+fc))) ;

dataOut = filter(b,a,e);


subplot(3,1,1);
%fourier of messege
y=abs(fft(m));
f=0:1/8:4*(fc+fm);
p=y(1:4*(fc+fm)*8+1);
plot(f,p);
title('m(t)');

subplot(3,1,2);
%fourier of modulatedd signal
my=abs(fft(e));
mp=my(1:4*(fc+fm)*8+1);
plot(f,mp);
title('modulated');

subplot(3,1,3);
%fourier of demodulatedd signal
dy=abs(fft(dataOut));
dp=dy(1:4*(fc+fm)*8+1);
plot(f,dp);
title('demodulated');
```

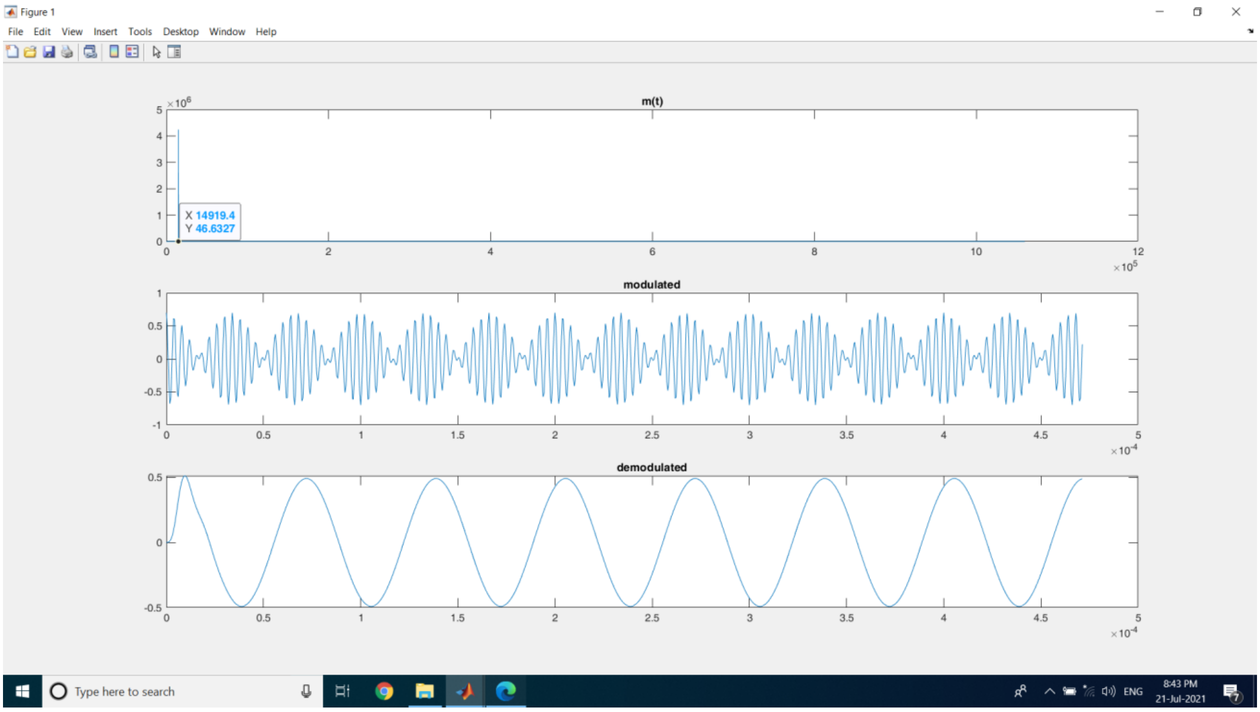

Figure 39 – time series plots of multiplier modulated and demodulated of 3kHz signal

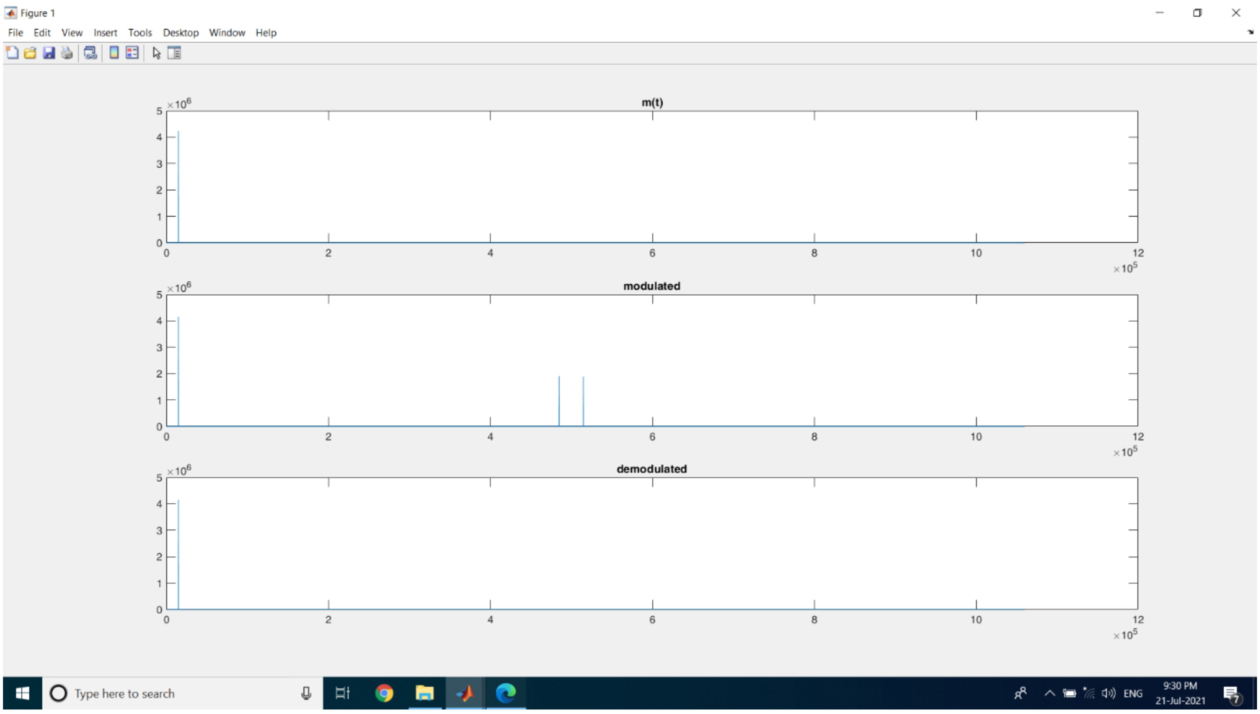

Figure 40 – spectrums of multiplier modulated and demodulated of 3kHz signal

Section II - Nonlinear Modulator/Demodulator

```
fm=15000;
fc=250000;
Fs=(8*(fm+fc));
t=0:1/Fs:8;
m=.5*cos(2*pi*fm*t);
c=1.4*cos(2*pi*fc*t);

%modulation
mx1=m+c;
mx2=m-c;
my1 = 2*mx1 + mx1.^2;
my2 = 2*mx2 + mx2.^2;
mz = my1-my2;
[b,a] = butter(3,[2*pi*(fc-fm)/Fs
2*pi*(fc+fm)/Fs],'bandpass') ;
freqz(b,a);
modulated_signal = filter(b,a,mz);

%demodulation
dx1 = modulated_signal+c;
dx2 = modulated_signal-c;
dy1 = 2*dx1 + dx1.^2;
dy2 = 2*dx2 + dx2.^2;
dz  = dy1-dy2;
[c,d] = butter(5,2*pi* 2 * fm/Fs) ;
%freqz(c,d);
demodulated_signal = filter(c,d,dz);


%plot
subplot(3,1,1);
%fourier of messege
y=abs(fft(m));
f=0:1/8:Fs/2;
p=y(1:Fs*8/2+1);
plot(f,p);
title('m(t)');

subplot(3,1,2);
%modulated
my=abs(fft(modulated_signal));
mp=my(1:Fs*8/2+1);
plot(f,mp);
title('modulated');

subplot(3,1,3);
%demodulated
```

```
dy=abs(fft(demodulated_signal));
dp=dy(1:Fs*8/2+1);
plot(f,dp);
title('demodulated');
```

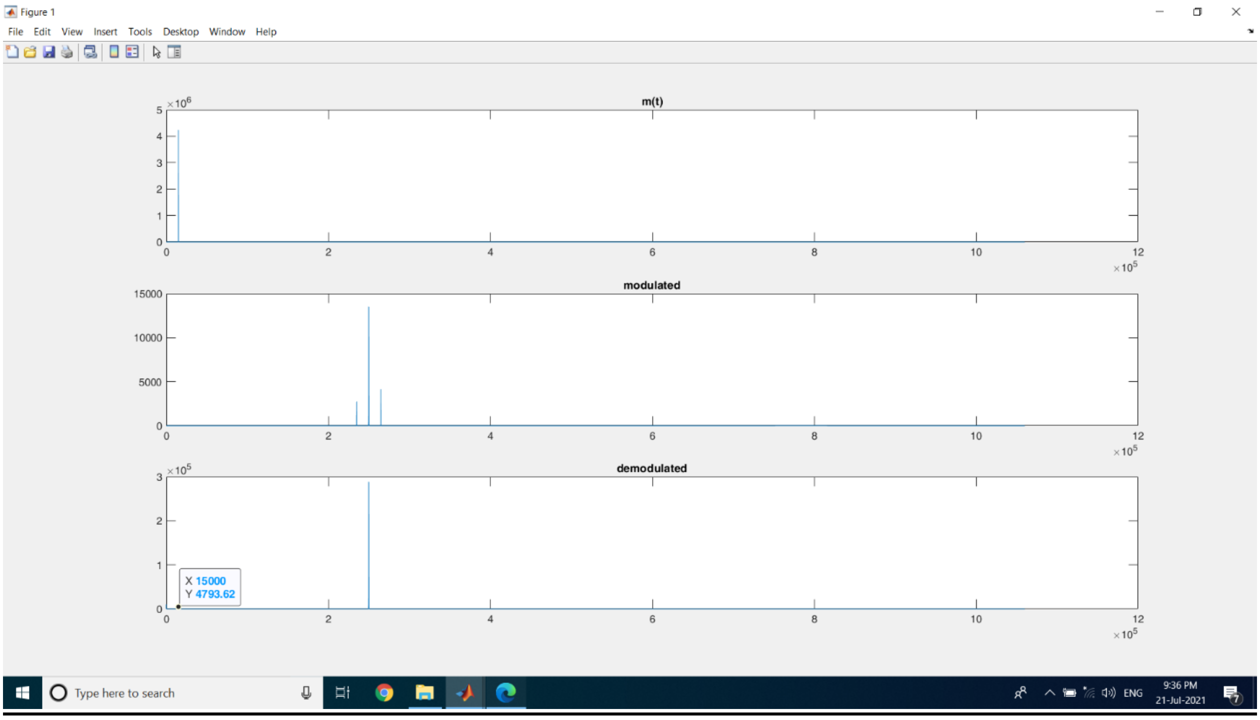

Figure 41 – spectrums of nonlinear modulated and demodulated of 3kHz signal

Section I – Effect of Phase Offset

```
fm=3000;
fc=250000;

t   = 0:1/(4*(fm+fc)):8;

m=.5*cos(2*pi*fm*t);
c=1.4*cos(2*pi*fc*t);
s=m.*c;
[b,a] = butter(5,2*pi* 2 * 15 * 1000/(8*(fm+fc))) ;

p=[];
for phi=0:pi/50:pi
r=cos(2*pi*fc*t+phi);            %RECIEVER OSCILLATING SIGNAL
e=s.*r;
dataOut = filter(b,a,e);
%p=[p max(dataOut(2000:3000))];
plot(t(1000:2000),dataOut(1000:2000));
hold on;
%legend('phi =',num2str(phi));
%hold on;
end

%h=0:pi/50:pi;
%plot(h,p)
```

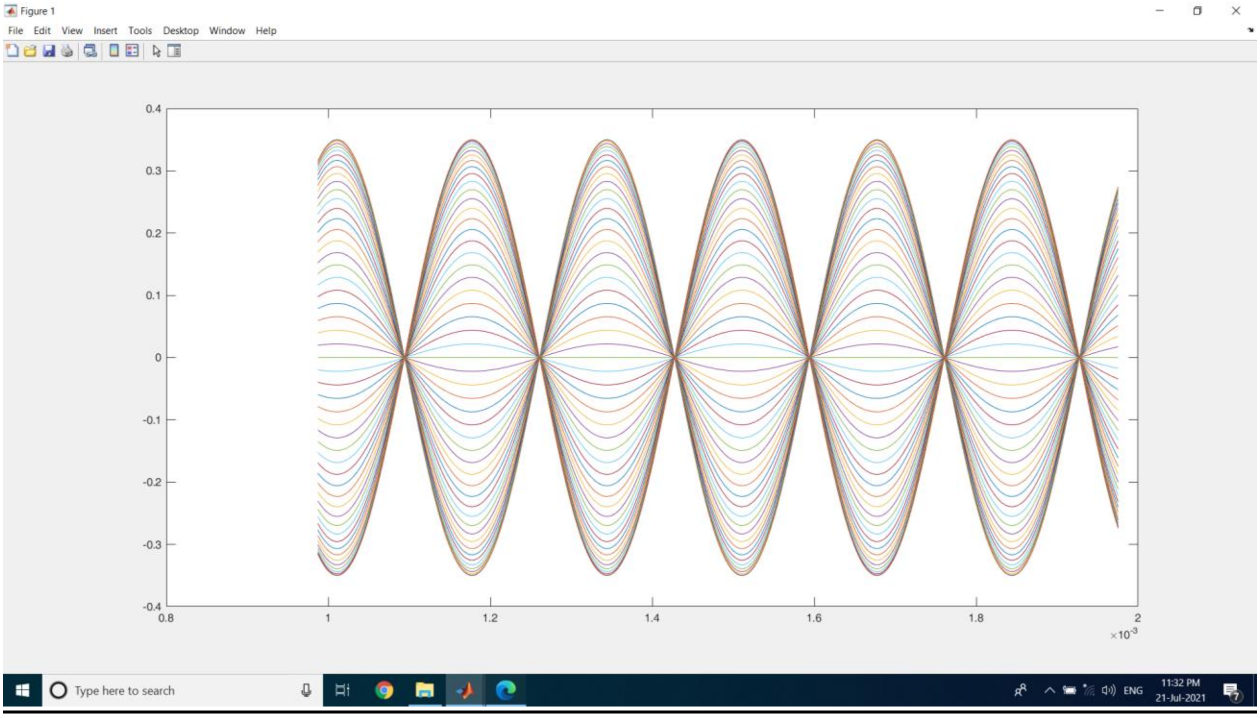

Figure 42 – amplitude change in multiplier demodulated 3kHz signal when receiver oscillators phase is changed gradually

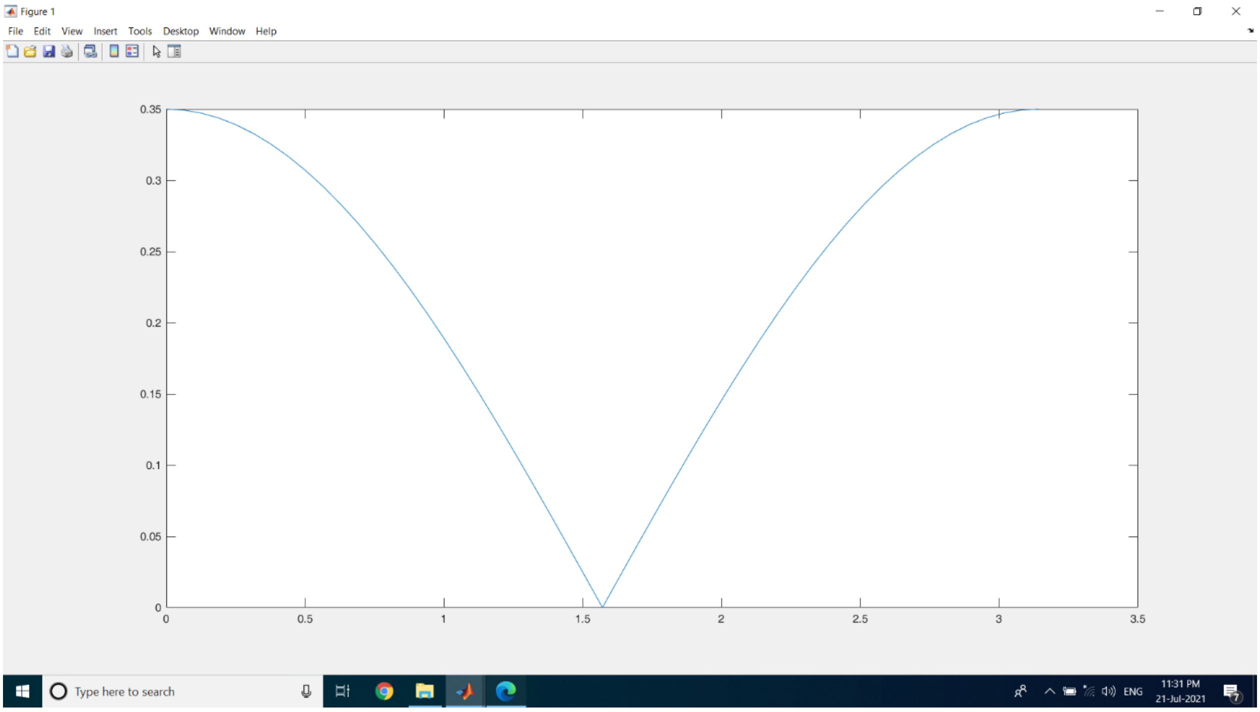

Figure 43 – attenuation of the signal when receiver oscillators phase is changed gradually