INDIAN INSTITUTE OF TECHNOLOGY, INDORE

Department of
Electrical Engineering
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Analysis Of FM Signal

(EE – 202)

Project Report

Semester IV

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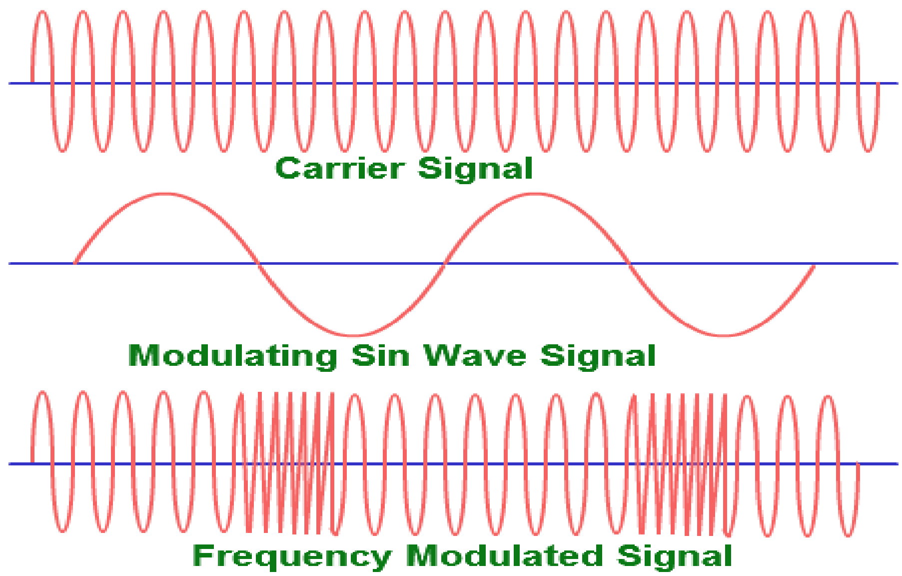
Introduction:

What is Frequency Modulation (FM)?

In a nutshell, it's the process of taking a signal of one frequency (known as the carrier frequency) and adjusting its frequency over time, in proportion to the amplitude of another signal known as the baseband signal (the baseband signal would typically be speech or music for example). The resultant signal is frequency modulated.



This type of modulation brings several advantages with it:

- ***Interference reduction.***
- ***Removal of many effects of signal strength variations.***
- ***Transmitter amplifier efficiency.***

Formulas And Techniques Used:

In order to characterise frequency modulated signals there are figures used that are the equivalent of those used for AM.

The modulation index and deviation ratio for FM are two of the major ones used. These appear to be very similar to each other but they are subtly different.

In view of the slight differences between the definitions for FM modulation index and FM deviation ratio, there is often confusion between the two terms.

Modulation index:

The **modulation index** of a modulation scheme describes by how much the modulated variable of the carrier signal varies around its unmodulated level.
In terms of a definition: the FM modulation index is equal to the ratio of the frequency deviation to the modulating frequency.

Thus the formula for the modulation index for FM is simple given by that shown below:

$$\boxed{m = \frac{\text{(Frequency deviation)}}{\text{(Modulation frequency)}}}$$

FM deviation ratio:

The modulation index will vary according to the frequency that is modulating the transmitted carrier and the amount of deviation. However when designing a system it is important to know the maximum permissible values. This is given by the deviation ratio and is obtained by inserting the maximum values into the formula for the modulation index.

Thus the FM deviation ratio can be defined as: the ratio of the maximum carrier frequency deviation to the highest audio modulating frequency.

$$\boxed{D = \frac{\text{(Max frequency deviation)}}{\text{(Max modulation frequency)}}}$$

Frequency modulation bandwidth:

In the case of an amplitude modulated signal the bandwidth required is twice the maximum frequency of the modulation. Whilst the same is true for a narrowband FM signal, the situation is not true for a wideband FM signal. Here the required bandwidth can be very much larger, with detectable sidebands spreading out over large amounts of the frequency spectrum. Usually it is necessary to limit the bandwidth of a signal so that it does not unduly interfere with stations either side.

As a frequency modulated signal has sidebands that extend out to infinity, it is normal accepted practice to determine the bandwidth as that which contains approximately 98% of the signal power.

A rule of thumb, often termed Carson's Rule states that 98% of the signal power is contained within a bandwidth equal to the deviation frequency, plus the modulation frequency doubled, i.e.:

$$\boxed{BT = 2(\Delta f + fm)}$$

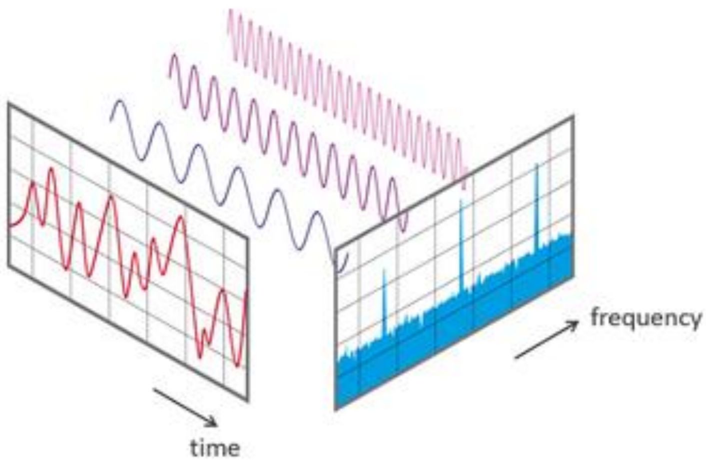
Key points for frequency modulation bandwidth and sidebands

There are a few interesting points of summary relative to frequency modulation bandwidth:

- The bandwidth of a frequency modulated signal varies with both deviation and modulating frequency.
- Increasing modulating frequency reduces modulation index - it reduces the number of sidebands with significant amplitude and hence the bandwidth.
- Increasing modulating frequency increases the frequency separation between sidebands.
- The frequency modulation bandwidth increases with modulation frequency but it is not directly proportional to it.

Fast Fourier Transform:

Fourier transform is is an algorithm used to convert the signals from time domain to frequency domain and the inverse Fourier transform is used to convert the signal back from the frequency domain to the time domain.The Fourier transform is a powerful tool to analyse the signals and construct them to and from their frequency components.



We will be using FFT to analyse our fm signal. By using FFT we will get the range of frequencies available in frequency modulated signal. Hence, we will be able to calculate frequency deviation and bandwidth of signal

Hilbert transform

The Hilbert transform is useful in calculating instantaneous attributes of a time series, especially the amplitude and the frequency. The instantaneous frequency is the time rate of change of the instantaneous phase angle. For a pure sinusoid, the instantaneous frequency is constant. The instantaneous phase, however, is a sawtooth, reflecting how the local phase angle varies linearly over a single cycle. For mixtures of sinusoids, the attributes are short term, or local, averages spanning no more than two or three points.

Demodulation:

Demodulation is extracting the original information-bearing signal from a carrier wave. A **demodulator** is an electronic circuit (or computer program in a software-defined radio) that is used to recover the information content from the modulated carrier wave.There are many types of modulation so there are many types of demodulators. The signal output from a demodulator may represent sound (an analog audio signal), images (an analog video signal) or binary data (a digital signal).

Mathematical Representation:

Message signal : **m = cos(2*pi*fm*t)**
Carrier signal : **c = sin(2*pi*fc*t)**
FM signal **: y = cos(2*pi*fc*t + (mi.*sin(2*pi*fm*t)))**
Where : pi is □
fm is frequency of message signal
fc is frequency of carrier signal
mi modulation index

Analysis include:

1. In Frequency Domain: We are taking FFT of message signal to get signal spectrum. Analysing signal spectrum using bessel function, we easily get □f (frequency deviation).
2. In Time Domain: We can also calculate □f (frequency deviation) without using FFT just by calculating instantaneous frequency. Hence to do this one can use Hilbert transform.The Hilbert transform is useful in calculating instantaneous frequency. So □f = (max(f)- min(f)) / 2 .
3. Demodulation: Demodulation of fm signal using fmdemod function of matlab (parameters as y: fm signal, fc: carrier frequency, Ns: Number of samples, fd_1: frequency deviation as obtained from frequency domain analysis)

Code:

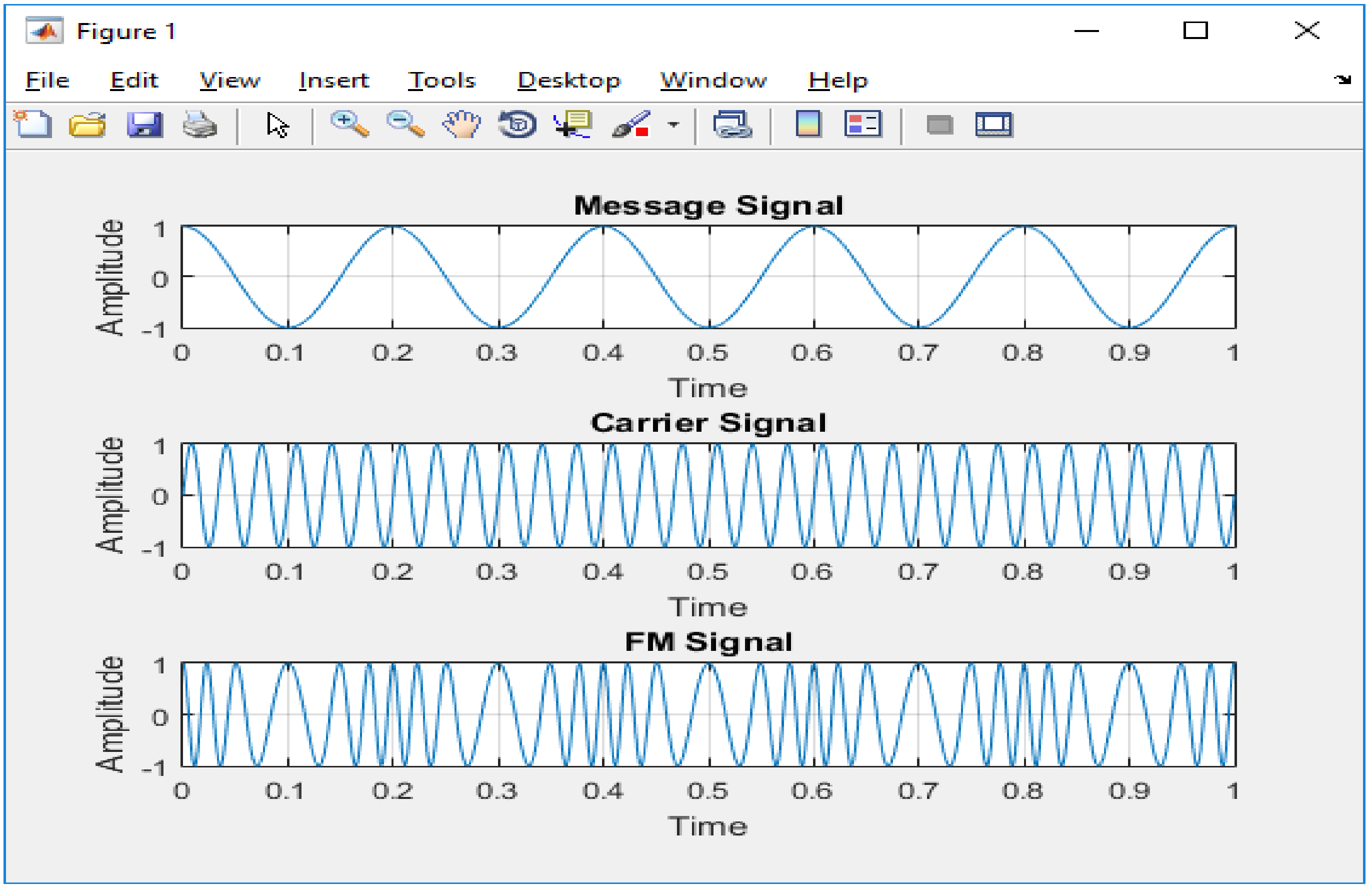
```
%% analysis of fm signal:
clc;
clear all;
close all;

fm = 5;  %Message Frequency
fc = 30; %Carrier Frequency
mi = 3;  %Modulation Index
t=0:0.0001:1;
```

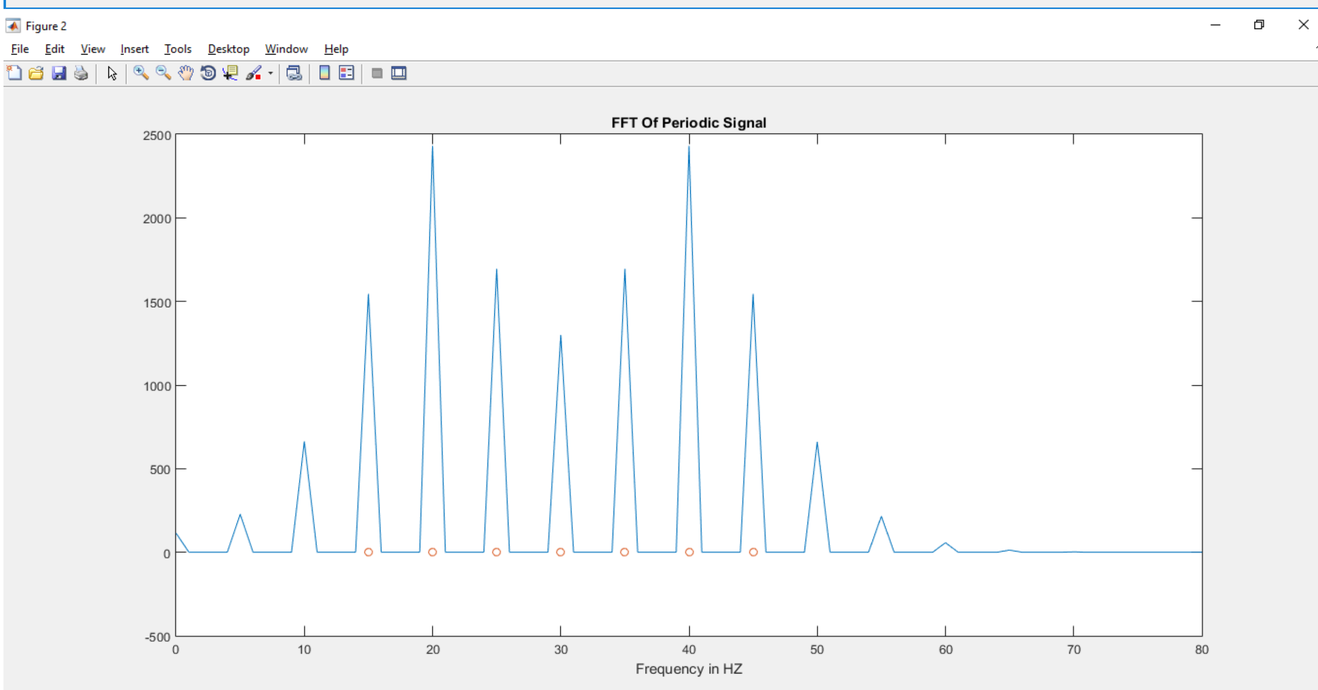
```
NS=10000;

%% Signal Definitions:
m=cos(2*pi*fm*t); %Message signal
subplot(3,1,1);
plot(t,m);
xlabel('Time');
ylabel('Amplitude');
title('Message Signal');
grid on;

c=sin(2*pi*fc*t); %carrier signal
subplot(3,1,2);
plot(t,c);
xlabel('Time');
ylabel('Amplitude');
title('Carrier Signal');
grid on;

y=cos(2*pi*fc*t+(mi.*sin(2*pi*fm*t)));%Frequency modulated signal
subplot(3,1,3);
plot(t,y);
xlabel('Time');
ylabel('Amplitude');
title('FM Signal');
grid on;


%% Analysis in Frequency Domain

figure(2);
ff = fft(y,NS); %fft of fm signal
ttt = 0:NS-1;
plot(ttt,abs(ff));
xlim([0 80]);
```

```
sidamp = (1/2)*besselj(0:mi,mi);
sidamp = [fliplr(sidamp(2:end)), sidamp];
sidf = (fc-mi*fm):fm:(fc+mi*fm); %collection of frequencies of peaks
plot(ttt,abs(ff),sidf,sidamp,'o')
xlim([0 80])
title('FFT Of Periodic Signal');
xlabel('Frequency in HZ');

%result: fd(frequency deviation)
fd_1 = (sidf(mi*2+1)-sidf(1))/2;

%% Analysis in Time Domain:
figure(3);
zzz = hilbert(y);  %hilbert transform of fm signal
instfreq = NS/(2*pi)*diff(unwrap(angle(zzz)));
plot(t(2:end),instfreq)
title('Instantaneous Frequency');
xlabel('Time');
ylabel('Frequency in Hz');
maxf = max(instfreq);
minf = min(instfreq);

%result: fd(frequency deviation)
fd_2 = (maxf - minf)/2;

%% Demodulation:
figure(4)
z = fmdemod(y,fc,10000,fd_1); %getting message signal again
plot(t,z);
title('Demodulated Signal');
xlabel('Time');
ylabel('Amplitude');
```

Result And Graphs:

1. fm = 5; fc = 30; mi = 3;





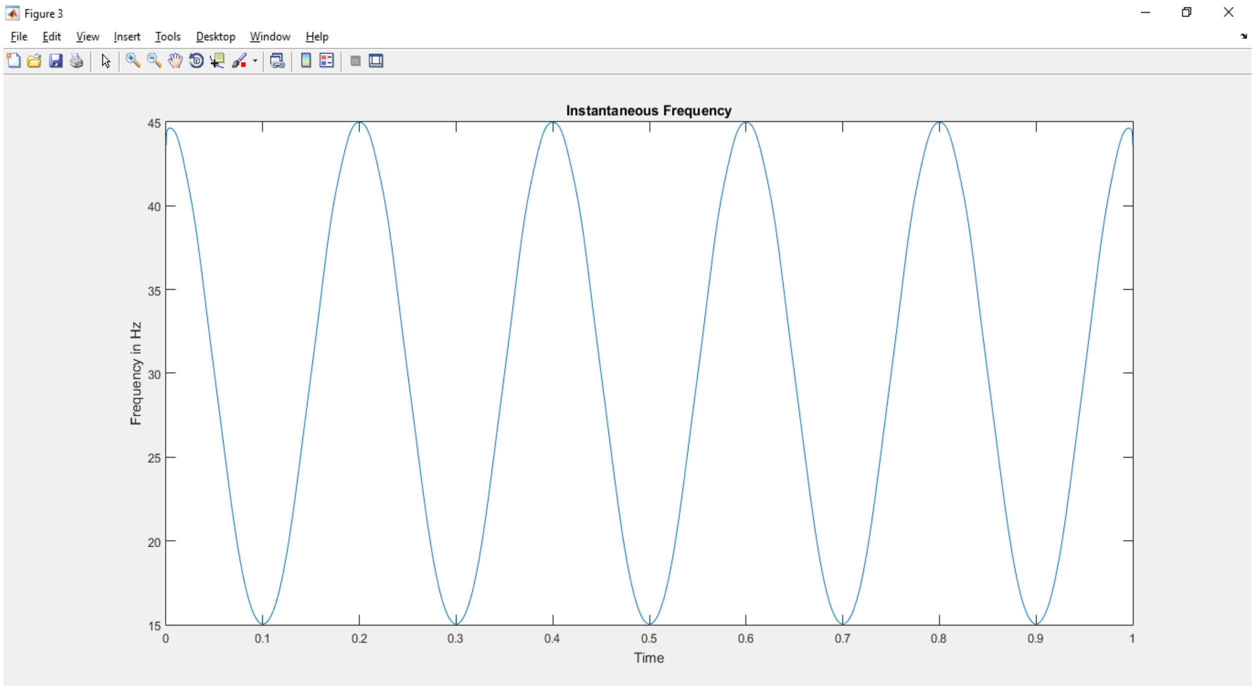


Figure 3
File Edit View Insert Tools Desktop Window Help
Instantaneous Frequency
Frequency in Hz
Time
45
40
35
30
25
20
15
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

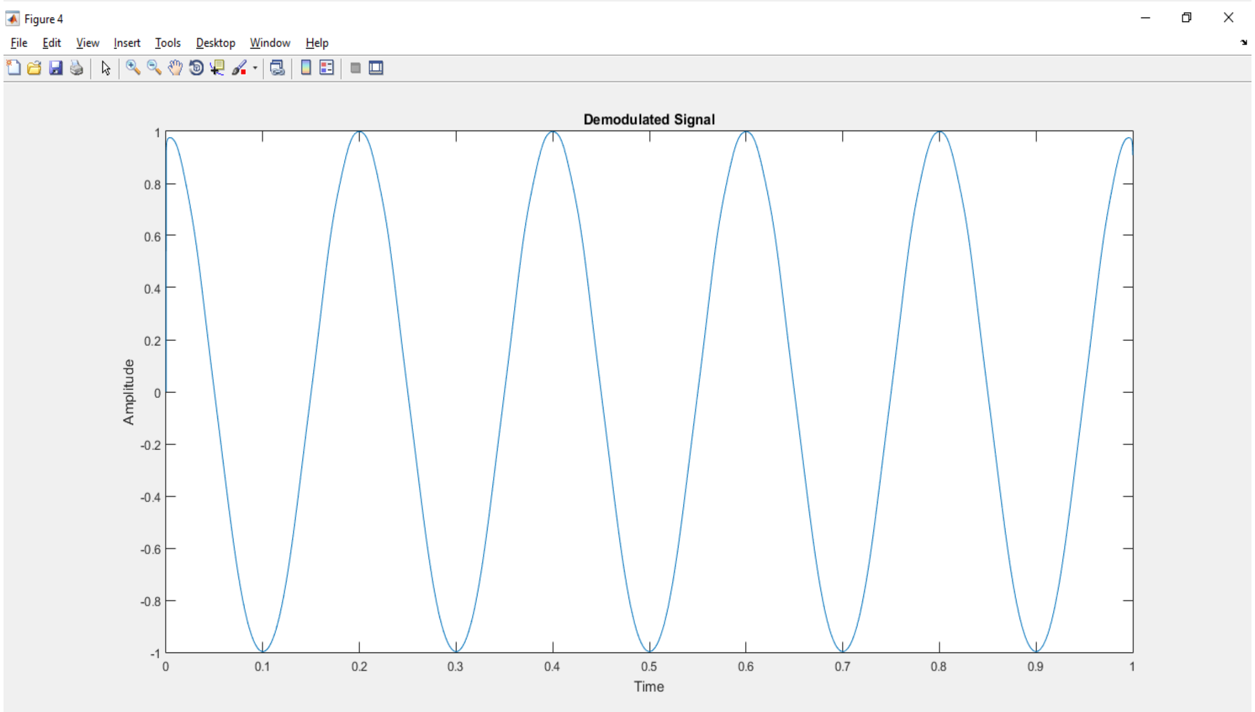
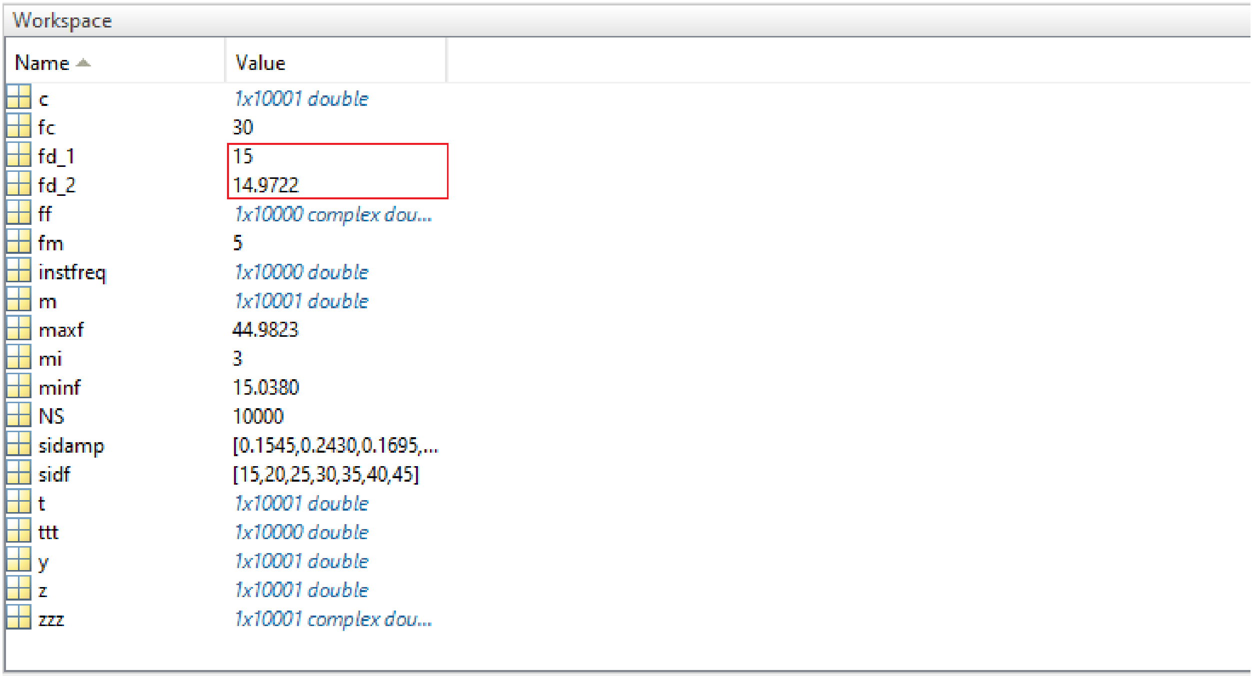


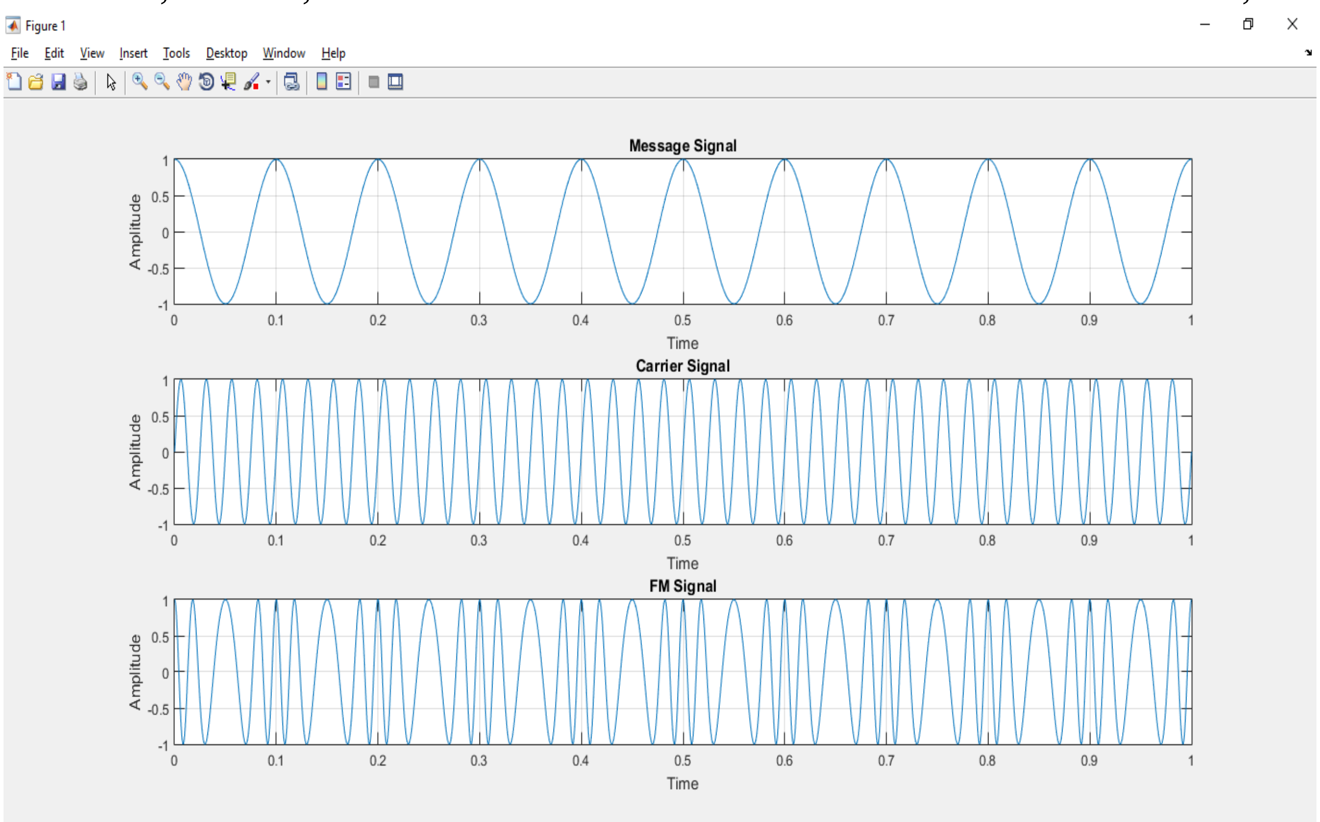
Figure 4
File Edit View Insert Tools Desktop Window Help
Demodulated Signal
Amplitude
Time
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



Workspace

Name	Value
c	1x10001 double
fc	30
fd_1	15
fd_2	14.9722
ff	1x10000 complex dou...
fm	5
instfreq	1x10000 double
m	1x10001 double
maxf	44.9823
mi	3
minf	15.0380
NS	10000
sidamp	[0.1545,0.2430,0.1695,...
sidf	[15,20,25,30,35,40,45]
t	1x10001 double
ttt	1x10000 double
y	1x10001 double
z	1x10001 double
zzz	1x10001 complex dou...

2. fm = 10;   fc = 40;   mi = 2;



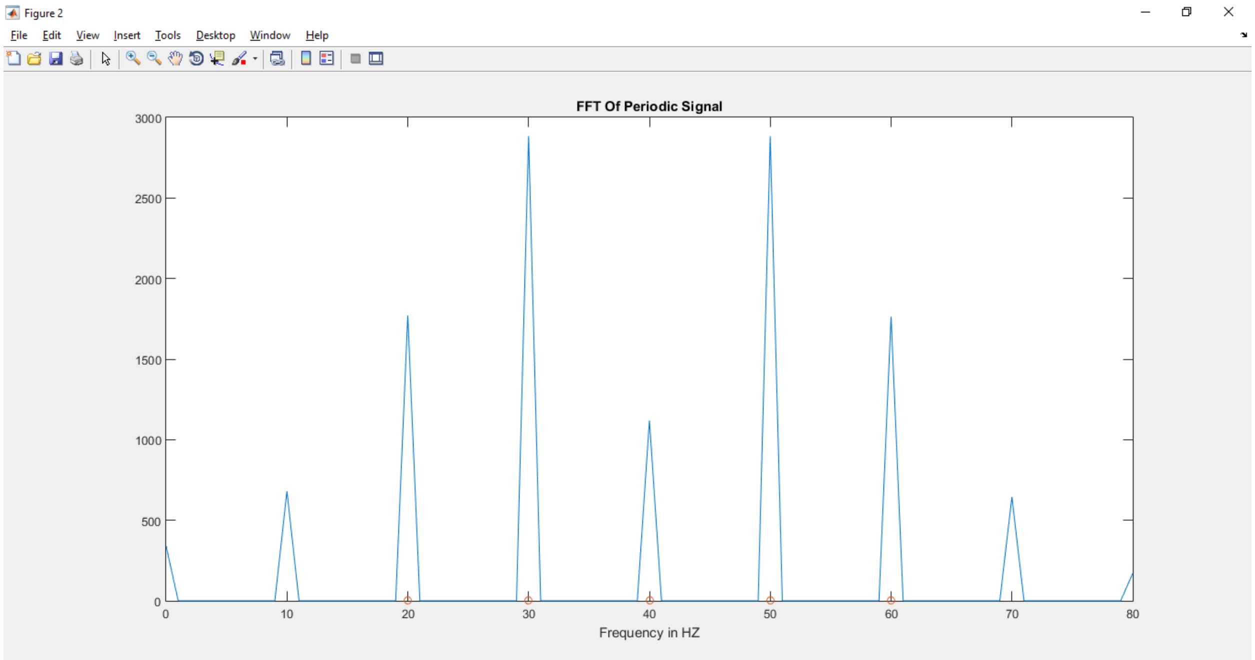


Figure 2
File Edit View Insert Tools Desktop Window Help
FFT Of Periodic Signal
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
Frequency in HZ

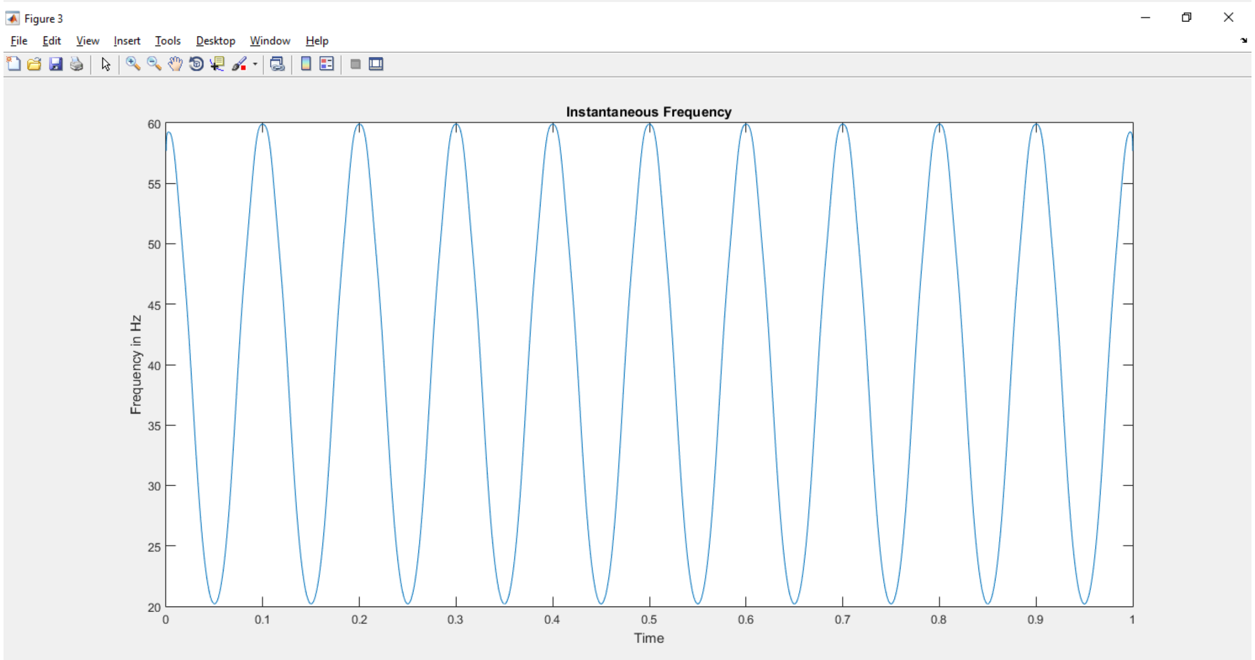
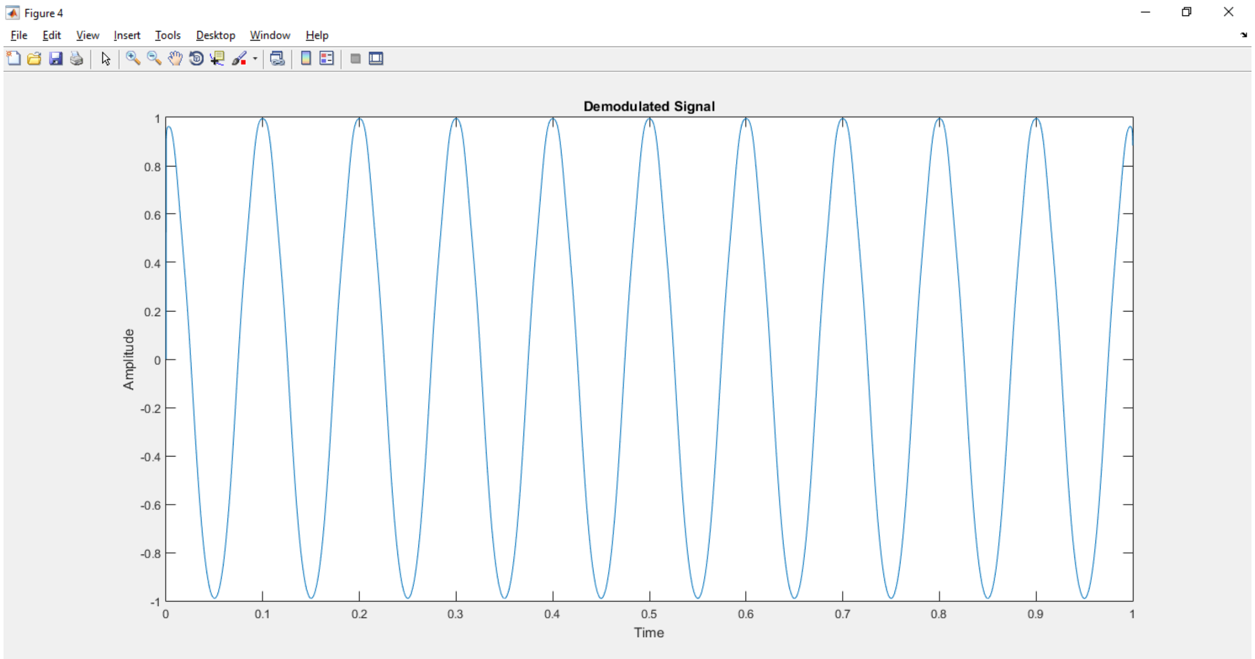


Figure 3
File Edit View Insert Tools Desktop Window Help
Instantaneous Frequency
60
55
50
45
40
35
30
25
20
Frequency in Hz
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time



Workspace

Name	Value
c	*1x10001 double*
fc	40
fd_1	20
fd_2	19.8495
ff	*1x10000 complex dou...*
fm	10
instfreq	*1x10000 double*
m	*1x10001 double*
maxf	59.8984
mi	2
minf	20.1995
NS	10000
sidamp	[0.1764,0.2884,0.1119,...
sidf	[20,30,40,50,60]
t	*1x10001 double*
ttt	*1x10000 double*
y	*1x10001 double*
z	*1x10001 double*
zzz	*1x10001 complex dou...*