Experiment No - 4

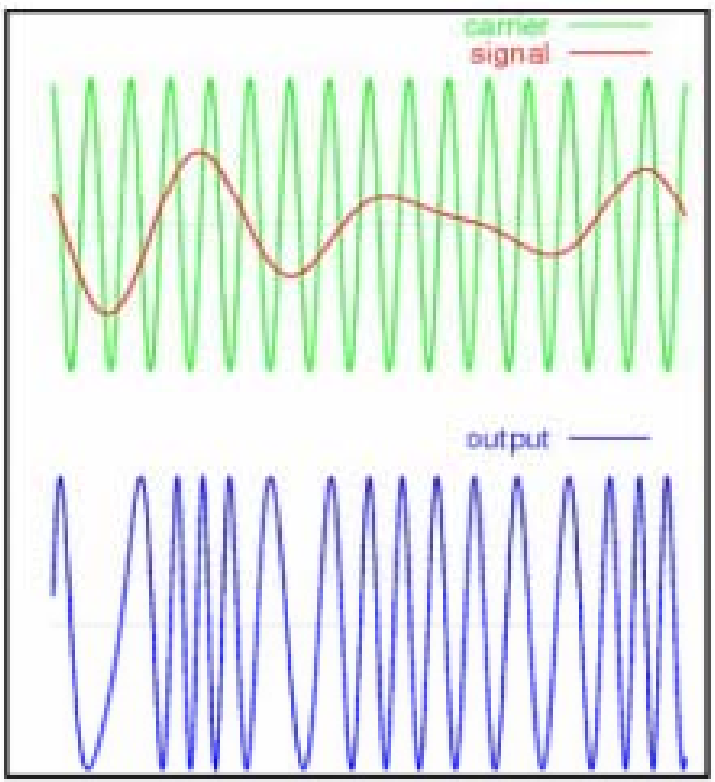
Objective- Study of Frequency modulation (FM) and demodulation with its application.

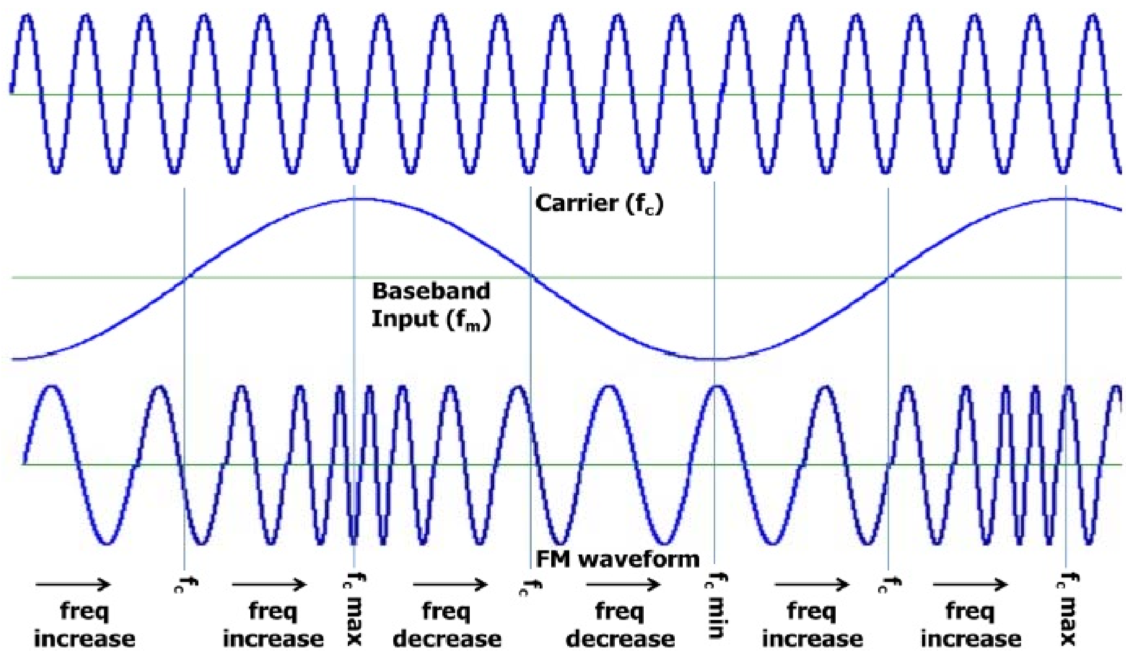
- The FM-modulated signal has its instantaneous frequency that varies linearly with the amplitude of the message signal. Now we can get the FM-modulation by the following:

$$\varphi(t) = \cos(2\pi f_c t + 2\pi k_f \int_0^t m(\tau)d\tau)$$

where Kf is the sensitivity factor, and represents the frequency deviation rate as a result of message amplitude change. The instantaneous frequency is:

$$\omega_i = 2\pi f_c + 2\pi k_f m(t)$$





Frequency Deviation

- The amount of change in the carrier frequency produced, by the amplitude of the input modulating signal, is called **frequency deviation**.

- The Carrier frequency swings between fmax and fmin as the input varies in its amplitude.

- The difference between fmax and fc is known as frequency deviation. $f_d = f_{max} – f_c$

- Similarly, the difference between fc and fmin also is known as frequency deviation. $f_d = f_c – f_{min}$

- It is denoted by Δf. Therefore $\Delta f = f_{max} – f_c = f_c – f_{min}$

Modulating signal Amplitude	**Frequency of Carrier**	**Deviation**
0V	100 MHz	Nil (Center frequency)
+1 V	105 MHz	+ 5 MHz
– 1 V	95 MHz	– 5 MHz

Frequency Modulation Equation

- The **FM equation** include the following
- $v = A \sin [\, w_c t + (\Delta f / fm) \sin w_m t \,]$

m = Modulation Index of FM

m = Δf/fm

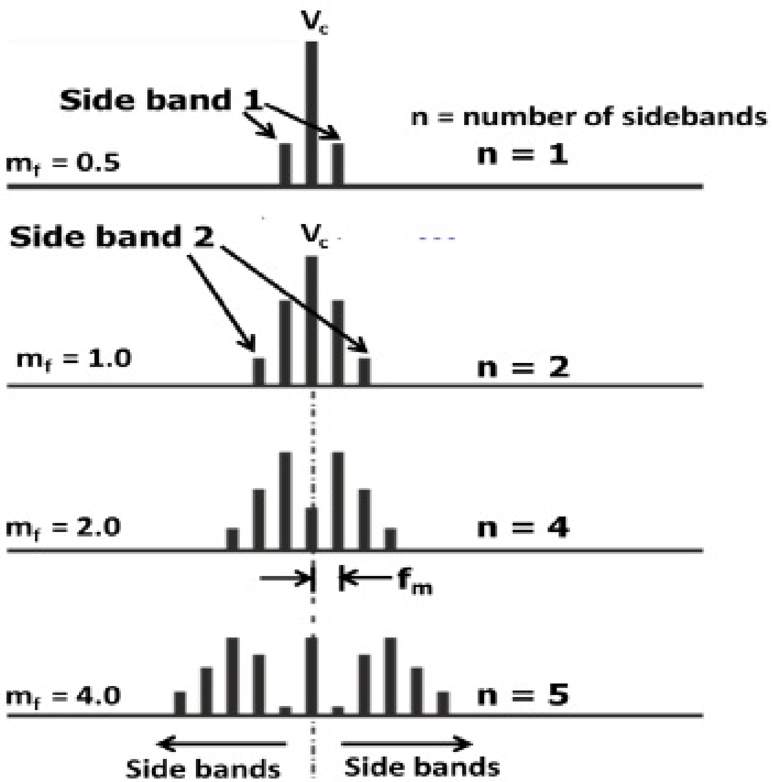
m is called the modulation index of frequency modulation.

Modulation index is the ratio of maximum change in the frequency of the carrier signal to the frequency of the carrier signal.

Bandwidth

FM signal spectrum is quite complex and will have an infinite number of sidebands as shown in the figure**.**

This figure gives an idea, how the spectrum expands as the modulation index increases. Sidebands are separated from the carrier by fc ± fm, fc ± 2fm, fc ± 3fm and so on.



Bandwidth of FM BWFM = **2 [Δf + fm]**.

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 and receiver are very complex and very expensive

Advantages of frequency modulation

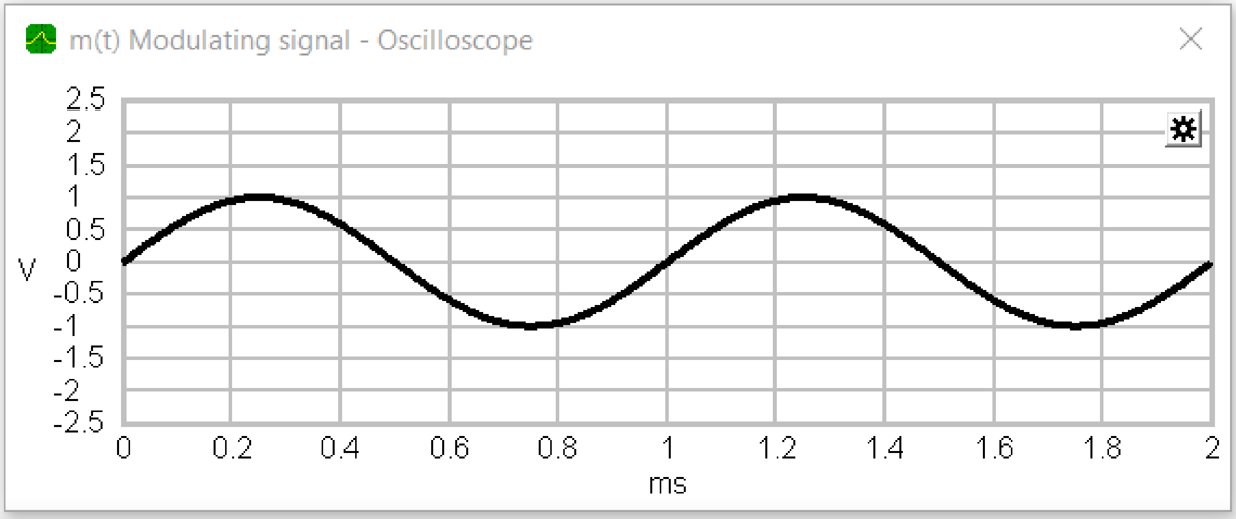
- FM is its resilience to noise and interference. It is for this reason that FM is used for high quality broadcast transmissions.

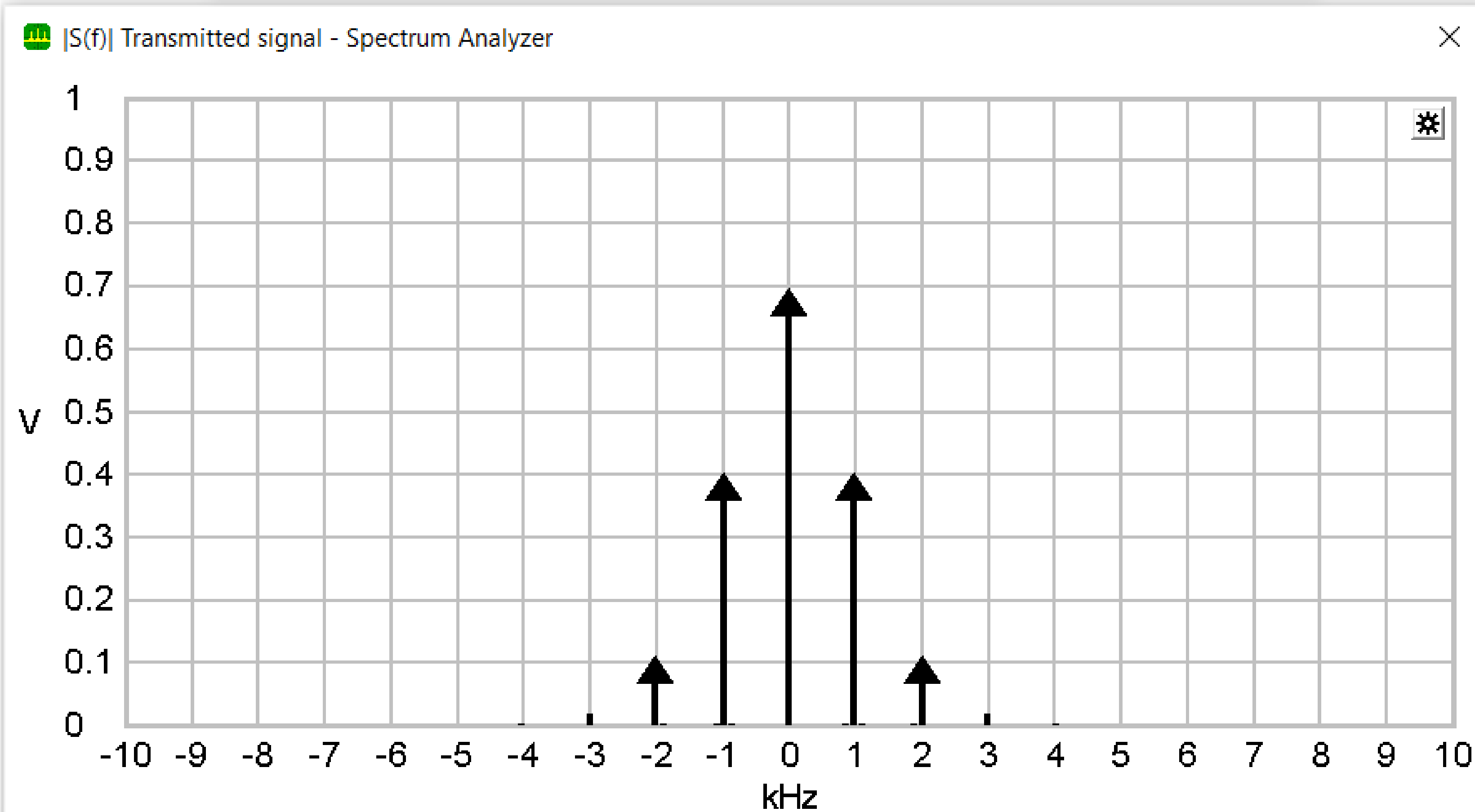
- FM ideal for mobile radio communication applications including more general two-way radio communication or portable applications where signal levels are likely to vary considerably.

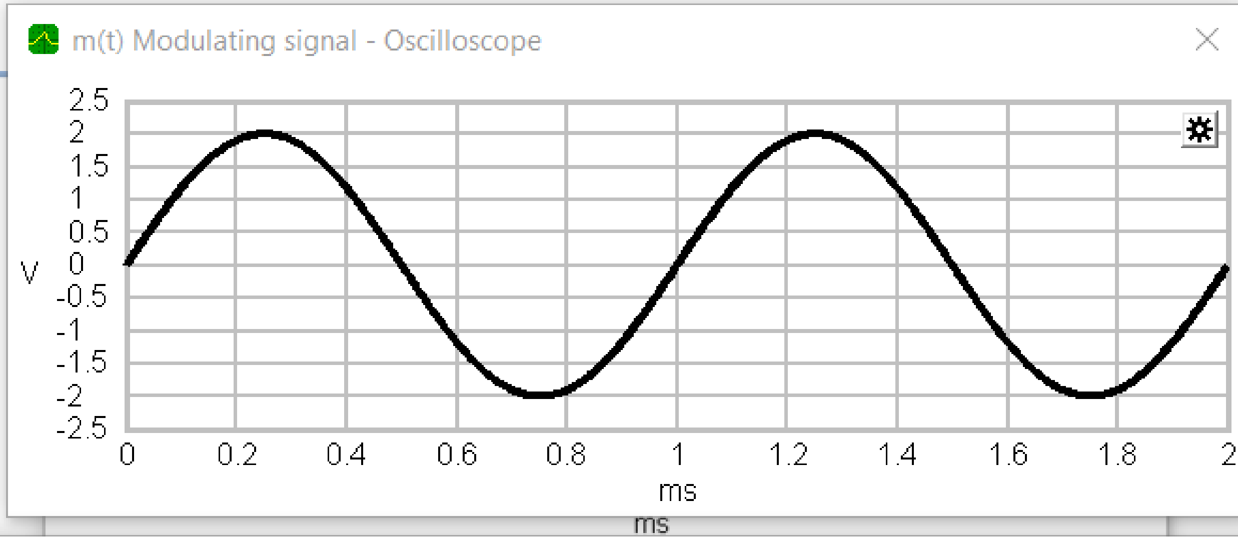
Applications

- The **applications of frequency modulation** include in FM radio broadcasting, radar, telemetry, & observing infants for seizure through EEG, music synthesis, two-way radio systems, magnetic tape recording systems, video broadcast systems, etc.

Frequency Spectrum


m(t) Modulating signal - Oscilloscope
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
V
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
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


m(t) Modulating signal - Oscilloscope
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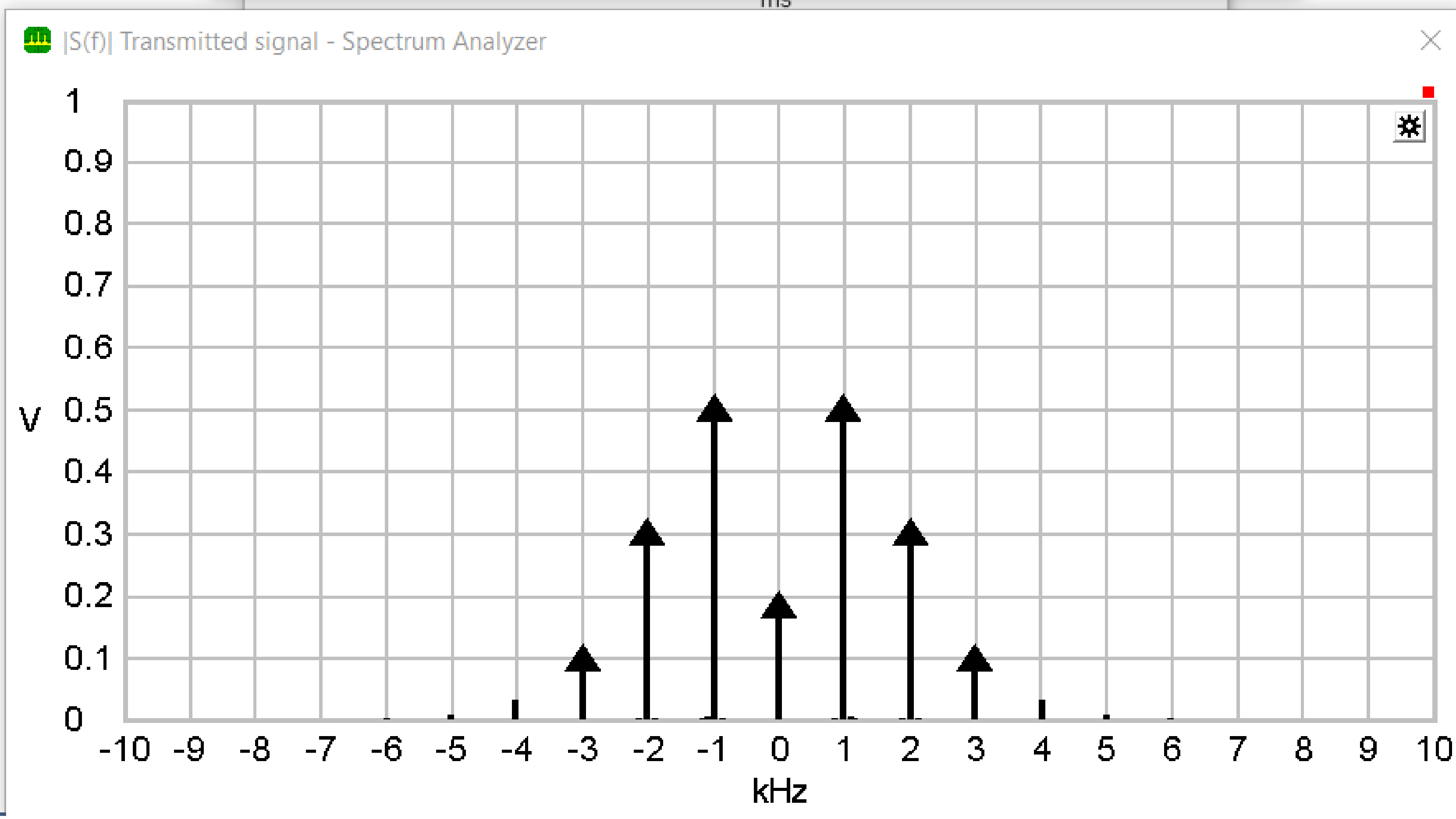
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
V
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
ms
ms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0.3
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0.1
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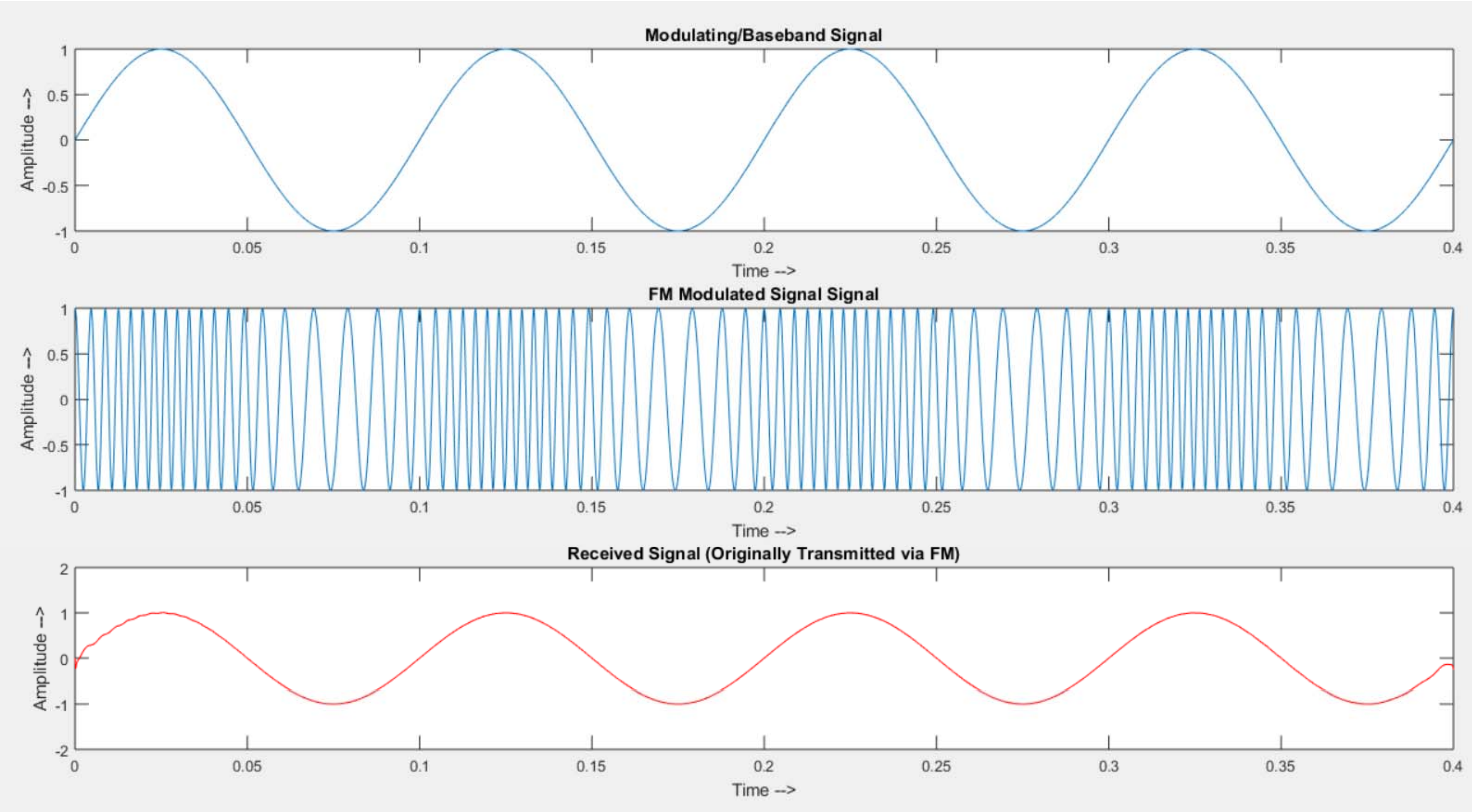
V
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
kHz

Matlab Simulation


Modulating/Baseband Signal
Amplitude -->
Time -->
FM Modulated Signal Signal
Amplitude -->
Time -->
Received Signal (Originally Transmitted via FM)
Amplitude -->
Time -->