EEE F311 COMMUNICATION SYSTEMS

Experiment 5: Frequency Modulation and Demodulation

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Section: P1
Aim: This experiment is intended to make the student to perform experiment on Frequency Modulation and Demodulations using MATLAB.

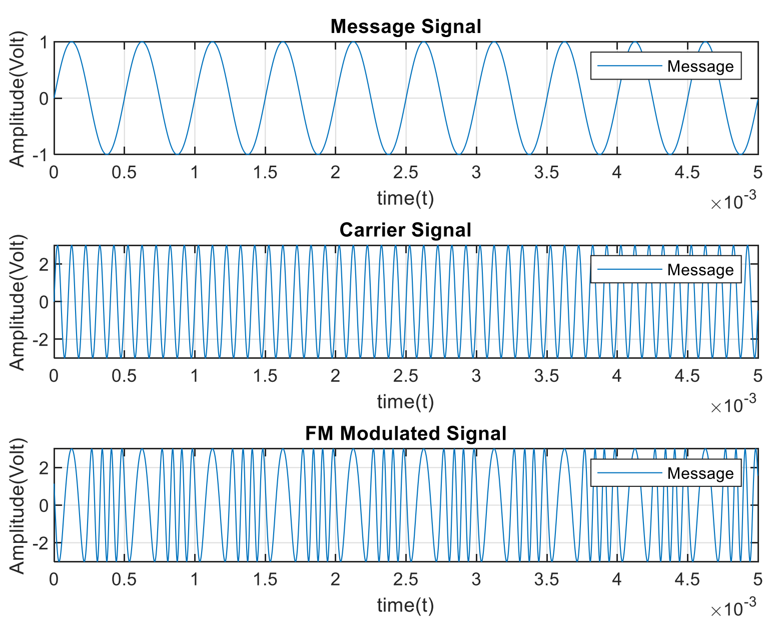
Codes are present in the **.m** files **partA.m** and **partB.m**

A – Generation of frequency modulated signal:

Generation of FM signal requires changing the instantaneous angular frequency of the carrier signal, according to message signal. That is: $\boldsymbol{\omega_i(t) = \omega_c + k_f * m(t)}$

where k_f is a proportionality constant known as the frequency sensitivity. Thus, the standard FM modulated signal is described by: $\boldsymbol{\varphi_{FM}(t) = A\cos\left[\omega c * t + kf * \int_{\infty}^{t} m(\alpha)d\alpha\right]}$

a. Consider the message signal ***m(t)*** to be a 2 KHz sine wave with excursion between (-1 V and + 1V) and the carrier signal to be a 10 KHz sine wave with 6V peak-to-peak value. Assume a frequency sensitivity value of 5500 rad/sec V. Generate the FM modulated signal as per the above equation.
b. Plot the message, carrier and FM modulated signals one below the other in a single plot.



c. Calculate the theoretical value $\Delta f = K_f * m_p$ where m_p is peak value of message signal.

    Δf = Kf*mp

    Kf = 5500 rad/sec

    mp = 1 V

    Δf = 5500 * 1

    Δf = 5500 rad/sec

d. With the chosen ***m(t),*** calculate the expected BW of the resulting FM signal that is obtained theoretically as $BW_{FM} = 2(\Delta f + B_m)$. Here, B_m ***(in KHz)*** is the essential bandwidth and can be taken as the frequency of ***m(t)***. Calculate $\beta = \Delta f / B_m$ for this case and Tabulate in Table 1 for various values of the message amplitude. These are the theoretical values.

    BWFM = 2(Δf + Bm)
    Bm = 2000
    BWFM = 2(Δf + Bm) = 2(5500/2*pi + 2000) = 2(2875.35)
    BWFM = 5750.70
    β = Δf / Bm = 5500 / (2000*2*pi)
    β = 0.4377

e. From theoretical analysis of FM band width for single tone message signal, the significant spectral components (n) that need to be considered while computing the bandwidth is given by $n = \beta + 1$. That is, from the peak spectral value, we must consider n spectral components while computing the bandwidth.

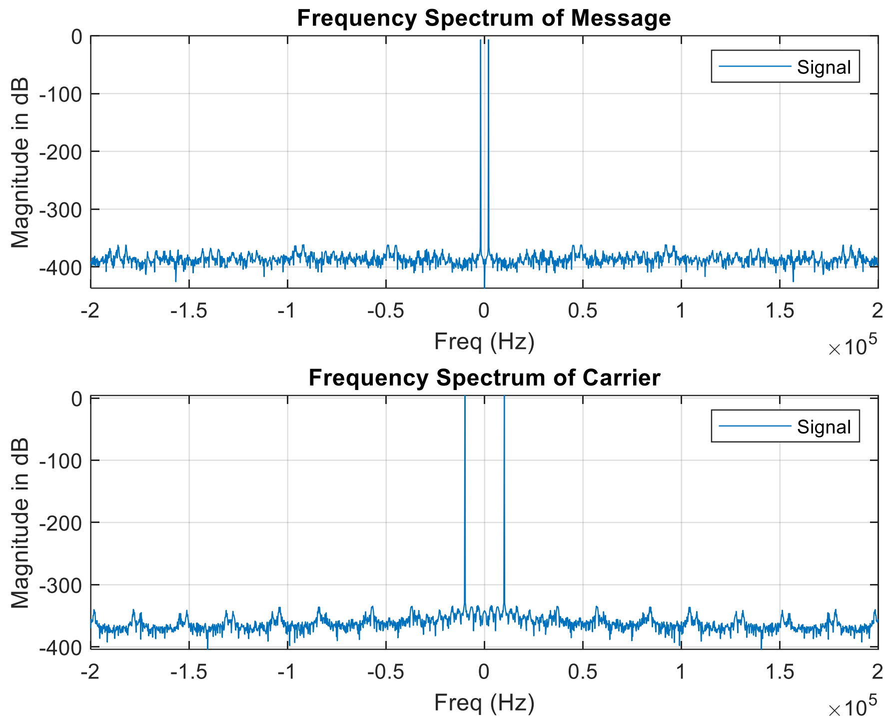
    n = β + 1 = 0.4377 + 1 = 1.4377
    n = 2

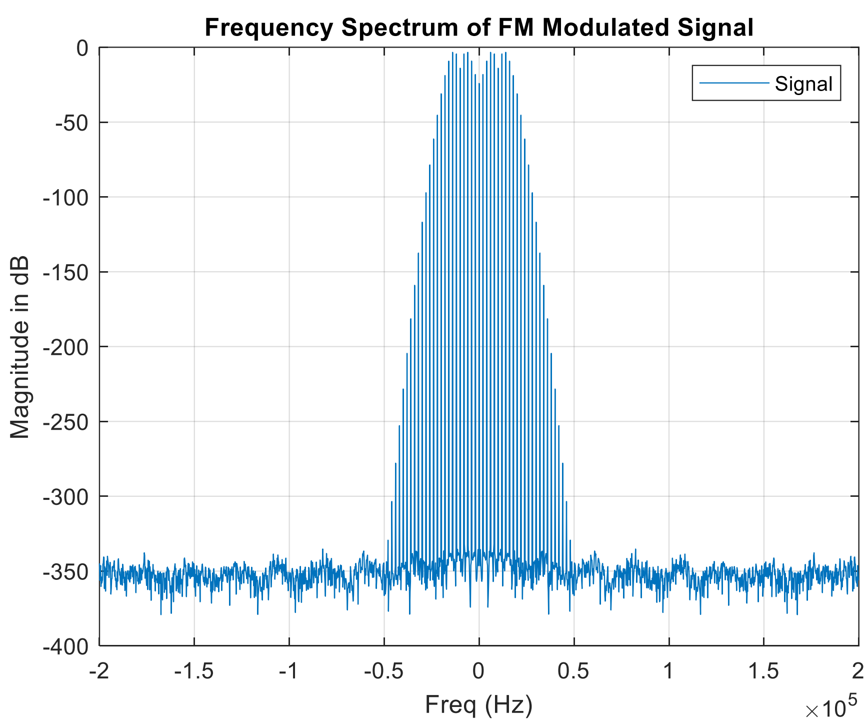
f. Obtain and plot the spectrum of the message, carrier and the FM modulated signal. The plots must be in absolute scale and in decibels. The plot in dB is obtained using the MATLAB command:

    *10*log(x)*

    where *x* represents the array containing the spectrum of the respective signal.

    Use the relation $n = \beta + 1$ to identify the relevant spectral components of the FM spectrum. What is the frequency value of the n^{th} spectral component (f_n)? The bandwidth is then given by $(BW_{FM})' = 2 * (f_n - f_c)$, where f_c is the nominal frequency of the carrier. Tabulate the observations in Table 1.





n = 2

(BWFM)’ = 2 * (fn–fc)

(BWFM)’ = 2 * (4000) = 8 kHz

g. How low (relative to the maximum value) is the power in the spectral component corresponding to ***n***? (***n_{pow}* is the power of the nth spectral component w.r.t max. value).**

Npow = 0.027 – 0.00125

npow = 0.02575

h. How do the theoretical and measured Bandwidths compare to each other?

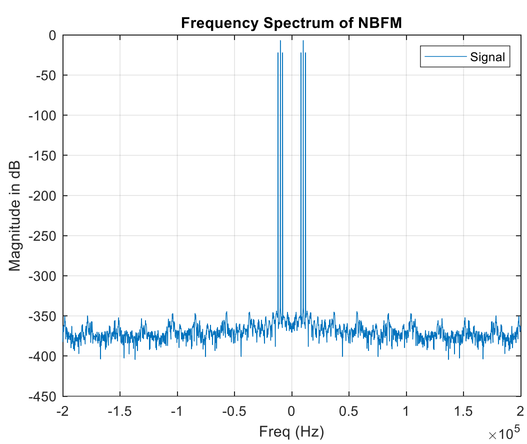
Sl. No.	***B_m***	***Δf***	***β***	***BW_{FM}***	***n***	***f_n***	***(BW_{FM})'***	**(*n_{pow}*)**
1.	**2000**	**5500**	**0.4377**	**5.75**	**2**	**14KHz**	**8KHz**	**0.02575**

Table 1: Frequency Modulation (Sine wave) Results

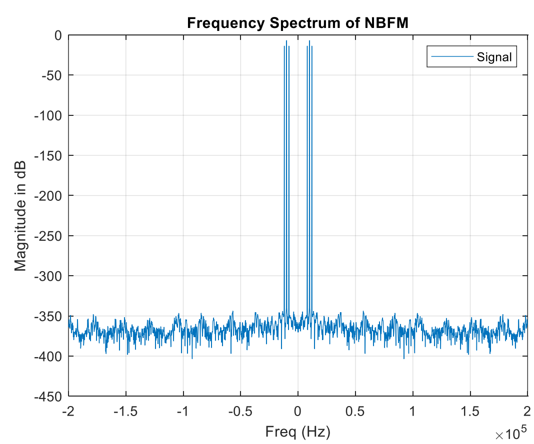
i. Generate a Narrow Band FM (NBFM) signal by implementing the equation:

$$\varphi_{NBFM}(t) = \cos(2\pi f_c t) + \frac{\beta}{2}\cos(2\pi(f_c + f_m)t) - \frac{\beta}{2}\cos(2\pi(f_c - f_m)t).$$

This equation is obtained from the original equation via an approximation that limits the value of β to be less than 1. Plot the spectrum of this signal in dB. Consider that spectral points whose amplitude is above -30 dB, relative to the maximum peak on the spectrum, and designate the frequency at that point as the essential bandwidth**.** Tabulate the results in Table 2 and comment on your observations. Repeat the experiment for various values of β.



β = 0.4377



β = 1

Changing β values changes the spectral components other than f_c

j. For each value of β, the corresponding message signal amplitude may be obtained for the general FM implemented earlier, also known as Wide Band FM (WBFM), using expressions given in c. and d. above. Tabulate the bandwidth of the WBFM signal in Table 2 for values of β used in NBFM bandwidth calculation. Compare the two bandwidths for each β.

Sl. No.	Type of FM	B_m	$(BW_{FM})'$
1. (β=0.4377)	NBFM	2KHz	4KHz
	WBFM	2KHz	8KHz
2. (β=1)	NBFM	2KHz	4KHz
	WBFM	2KHz	5.75KHz

Table 2: Narrow and Wideband Frequency Modulation (Sine wave) Results

In both cases, we can see that WBFM > NBFM, and the difference between them grows as beta increases to 1.

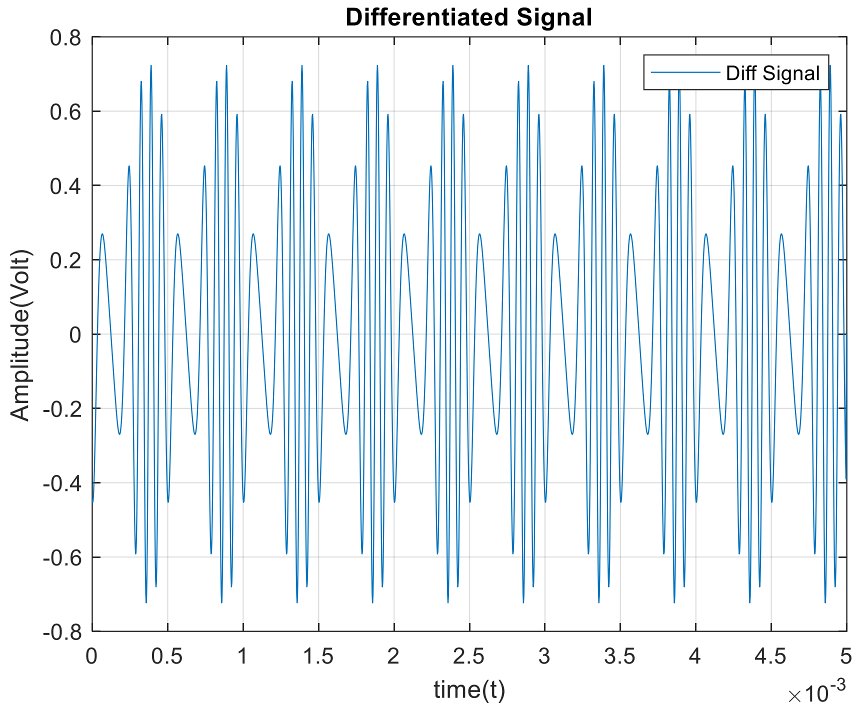
B – Demodulation of Frequency Modulated Signal:

There are many methods of demodulating an FM signals such as *slope detector*, the *Foster-Seeley discriminator*, the *ratio detector*, the *phase-locked loop* (PLL), the *quadrature FM demodulator* and the *zero-crossing detector*. In this experiment, we will be demodulating the FM modulated signal as follows:

a) The FM modulated signal is first differentiated. This is achieved using the MATLAB command:

diff(x)

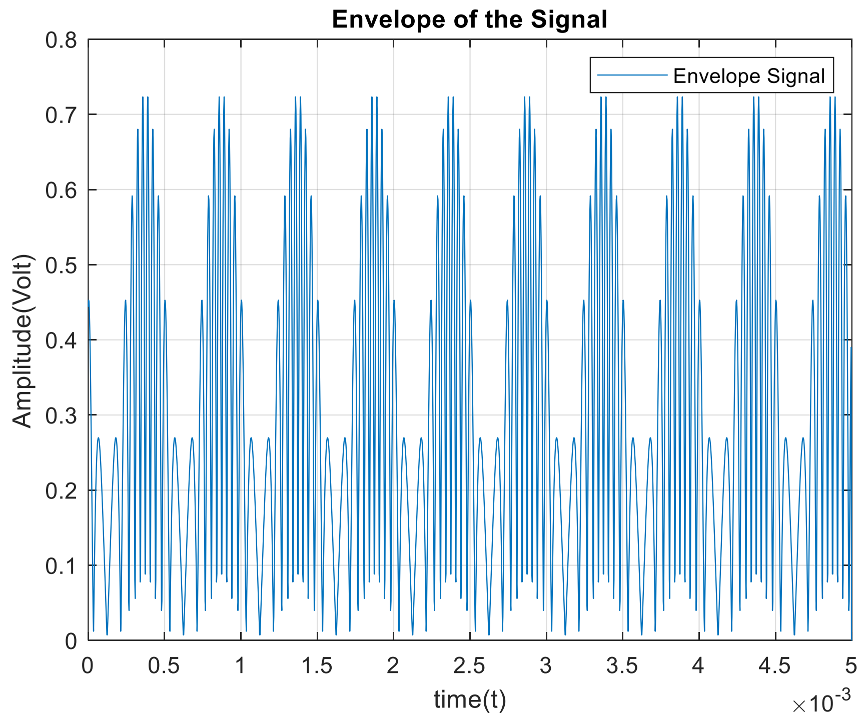
where *x* is the signal to be differentiated.
Since differentiation is implemented as finite difference in MATLAB, the array containing the derivative signal will have one sample less that the message/carrier/modulated signal array. Hence, we zero pad the array containing the derivative signal to make it the same length as the message/carrier/modulate signal array.



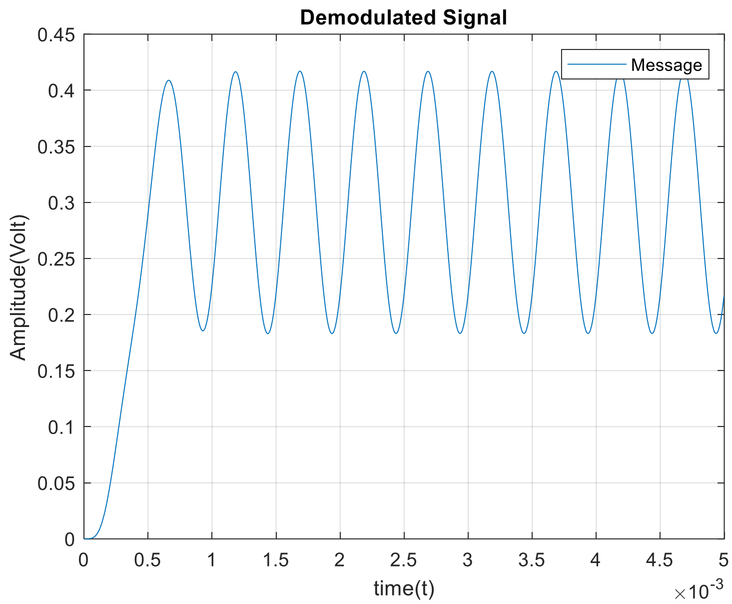
b) The differentiated FM modulated signal is passed through an envelope detector. This is achieved in MATLAB using the command:

abs(x)

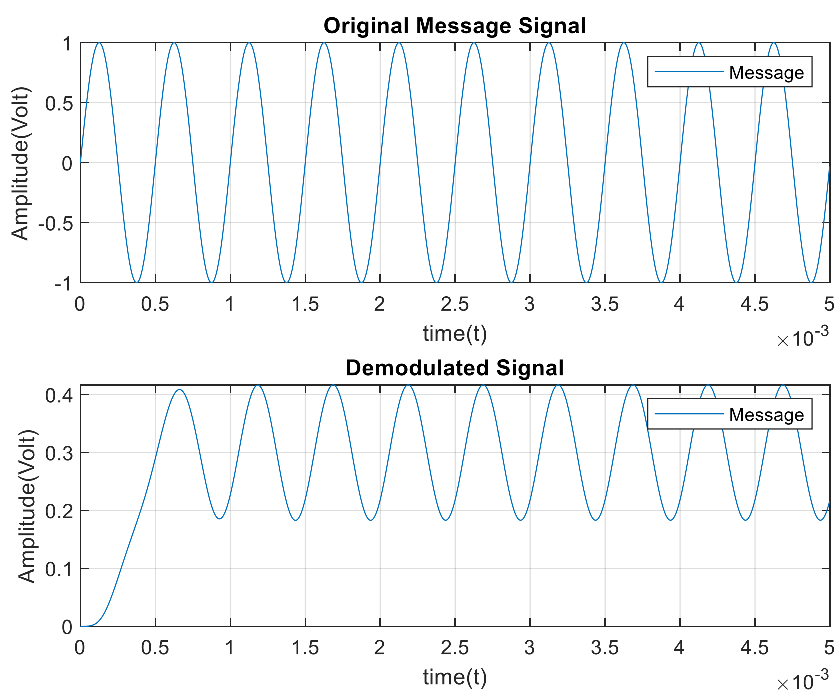
where *x* is the signal, whose envelope is to be obtained.

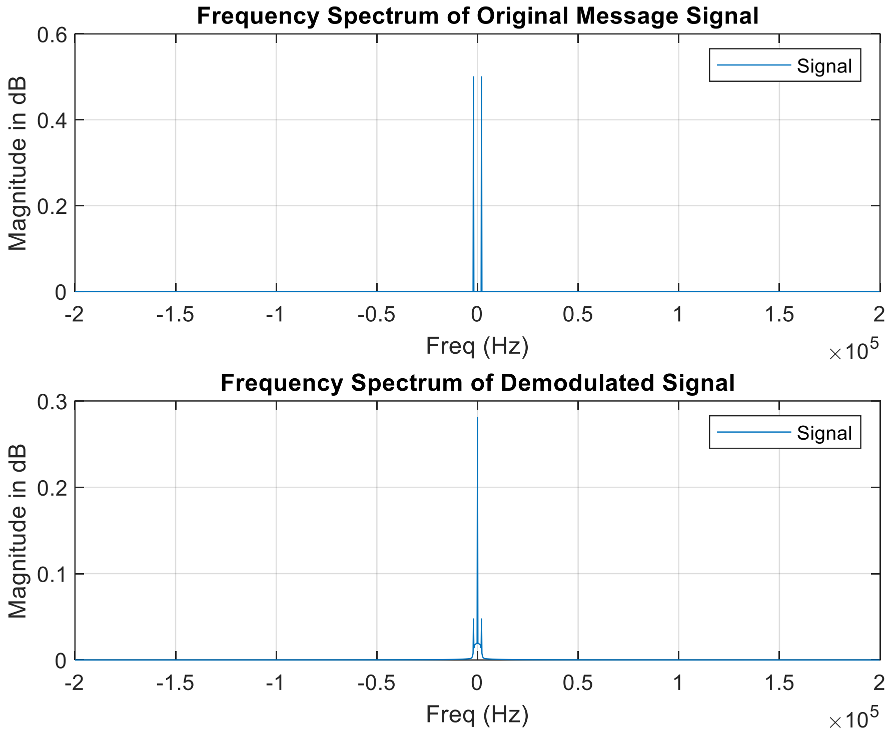


c) The resulting envelope is then passed through a low-pass filter to obtain the original message signal. The cut-off frequency of the filter may be adjusted to obtain a stable demodulated signal. Similarly, the gain of the filter may be accordingly adjusted. The low-pass filter may be implemented either using the MATLBA command "*lowpass*" or using a combination of MATLAB commands "*butter*" followed by "*filter*". If using the latter, it is advised to use a order of 5 or more for the command "*butter*".



d) Plot the message and demodulated signals one below the other. Obtain and plot the spectra of the message and demodulated signals one below the other. Comment on these plots





C –Conclusions:

List out your learning's from the experiment.

In this experiment we learnt the frequency modulation and demodulation techniques along with Narrow band frequency modulation and wide band frequency modulation.