BIRZEIT UNIVERSITY

Faculty of Engineering & Technology

Electrical & Computer Engineering Department

COMMUNICATIONS LAB

ENEE4113

Experiment No. 4

FM & PM Experiment

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1.Abstract:

This experiment aims to learn the theoretical aspect of frequency modulation (FM) and phase modulation (PM) and then transform the skills into practical skills. The practical aspect includes several aspects including frequency modulation and demodulation, and exploring zero carrier crossing concepts. phase modulation is also recognized in both time and frequency domains.

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2.Theory:

2.1. Frequency modulation:

By modulating frequency, information is converted into an electronic signal for transmission. It involves encoding information, such as music or speech, onto a signal by changing the frequency of the signal itself. It requires a large area of airwaves, typically about 200 kilohertz (kHz) of bandwidth. FM frequency modulation is used in radio to transmit audio signals due to its ability to deliver clear, high-quality sound.[1]

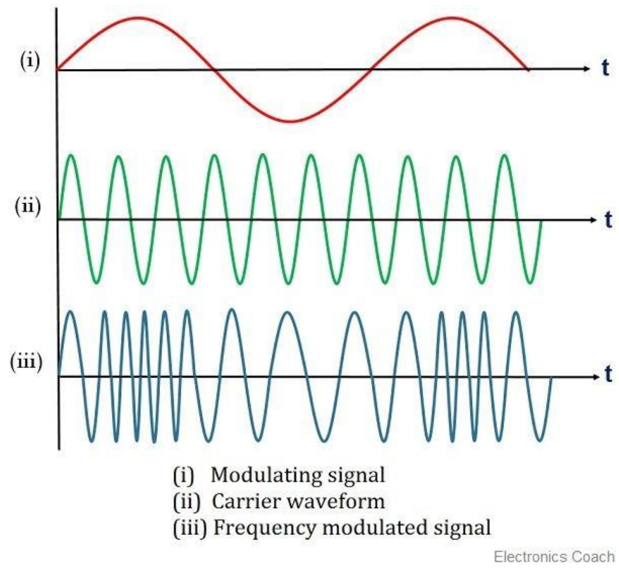


Figure 1.Waveform-for-frequency-modulation [1]

2.2.Frequency demodulation:

Frequency demodulation is the opposite of frequency modulation. It involves extracting the original message from the modified carrier signal after receiving, filtering and amplifying the signal.[2]

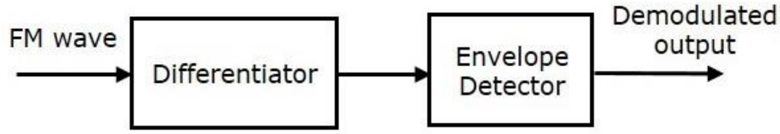


Figure 2.frequency demodulation

2.2.1.FM Demodulation by envelop detector:

Through the envelope detector the original message signal is recovered by removing all high frequency components from the modified signal. The capacitor and resistor work together as a low-pass filter. It allows only the low-frequency signal to pass through, while effectively blocking the high-frequency carrier signal. The combination of capacitor and resistor ensures that the envelope representing the original message signal is successfully recovered from the modified signal.[3]

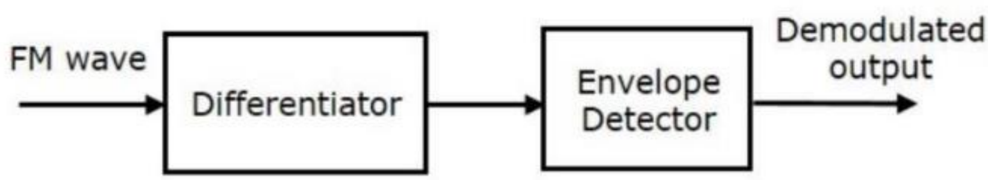


Figure 3.:FM Demodulation by envelop detector block diagram [3]

2.3. Phase-locked loop (PLL):

Phase locked loop (PLL) is a method used to recover the original message signal from a frequency modulated (FM) signal. Operating as a negative feedback system, it is designed to "lock" the frequency of the incoming waveform. This method contains a key component, a phase detector, which generates a signal that reflects the phase difference between the incoming waveform and the VCO output. A loop filter smoothes this signal, which Creates a consistent control signal for the VCO.[2]

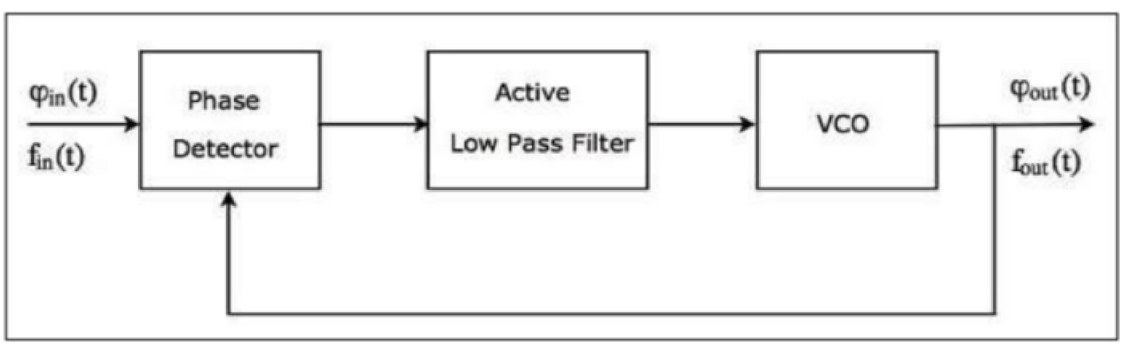


Figure 4.phase-locked loop (PLL) block [2]

2.4. phase modulation:

Phase modulation is a basic form of angle modulation, which encodes the message signal by differences in the direct phase of the carrier wave. This modification method also includes manipulating the timing or phase of the carrier wave to represent the information effectively..[4]

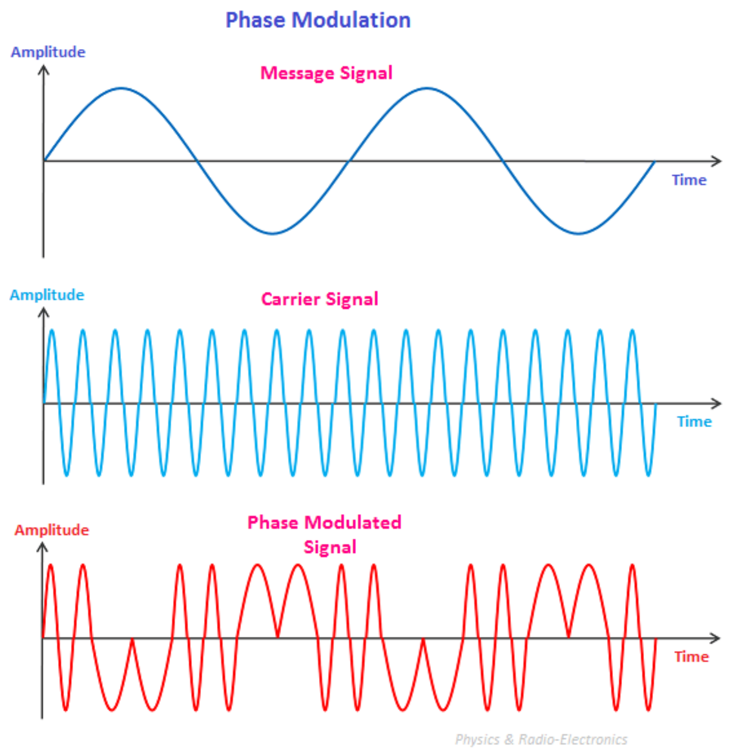


Figure 5 phase modulation[4]

3. Procedure:

3.1. Frequency Modulation in the Time Domain:

In general:

$m(t)=Am\cos(2\pi fmt)$

$c(t)=Ac\cos(2\pi fct)$

In this case m(t) = 5cos(2*pi*100t)

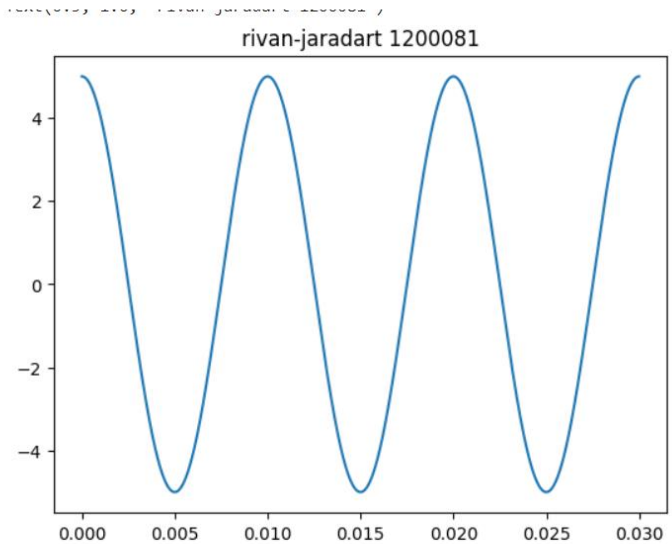


Figure 6.m(t) in time domain

So from figure 1 we notice the amplitude of massage signal is 5 same as Am in m(t) =5cos(2*pi*100t

Now the C(t) was produced as :

c(t)=5os(2π1000t)

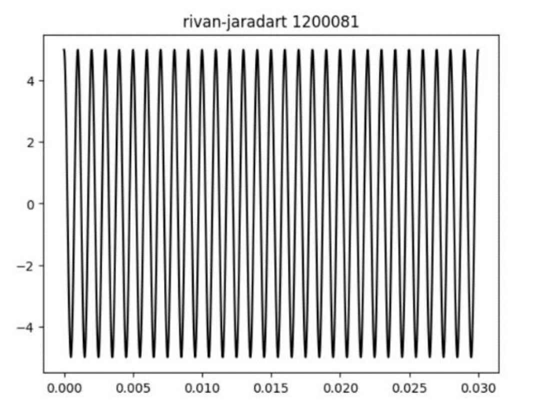


Figure 7.c(t) in time domain

In general $s(t)=A_c \cos(2\pi f_c t+\beta \sin(2\pi f_m t))$, where $\beta=k_f A_m/f_m$, When the modulating signal m(t) is sinusoidal

Kf=100, the modulation index β=(100*5)/100=5

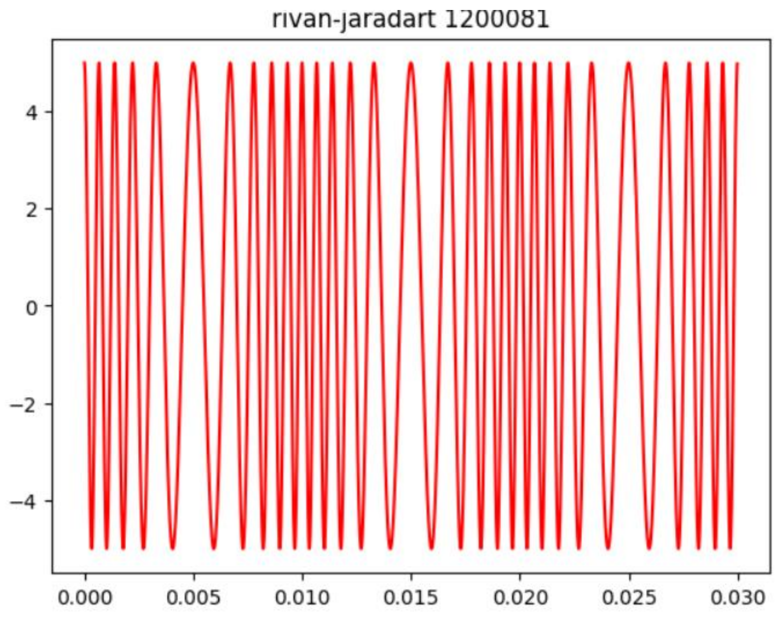


Figure 8.s(t) in time domain

Here in this figure the s(t) was generated as $s(t)=5\cos(2*pi*1000t+5\sin(2\pi 100t))$ and it has constant amplitude and varying instantaneous frequency.

- Message signal $m(t)=\cos(2\pi f_m t)$ with the modulate signal $s(t)=A_c\cos(2\pi f_c t+\beta\sin(2\pi f_m t))$

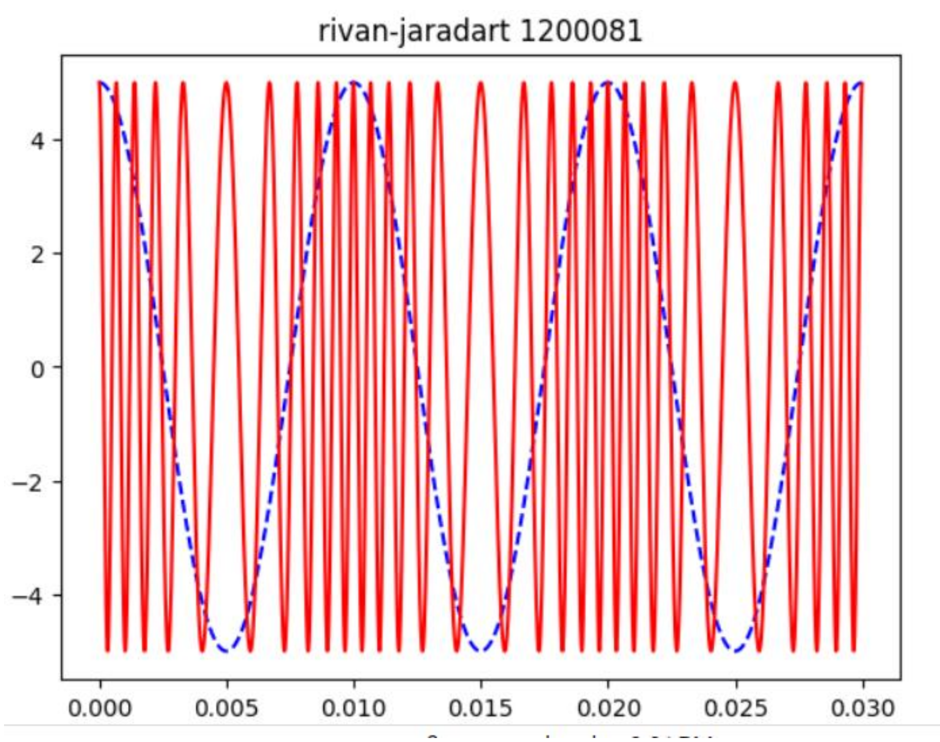


Figure 9.s(t),m (t) in time domain

From the message signal and the modulate signal , we notice that as the amplitude of the message increases, the instantaneous frequency of the modulate signal increases

Now, let us vary the value of Am and see how it affects the FM modulated signal.

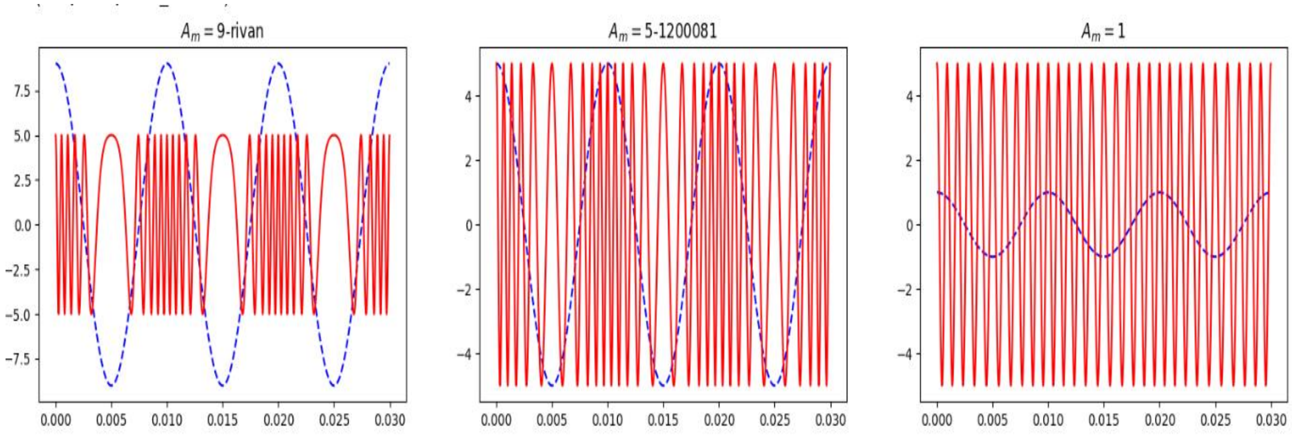


Figure 10.m(t),s(t) with vary value of Am

We notice from the previous images that there was an effect on the frequency deviation Δf=kfAm for the FM modulation after changing the Am values. However, changing the values of Am does not affect the amplitude of c(t) and s(t), which remains limited to (±5V).

change fm and observe the effect on the modulated signal.:

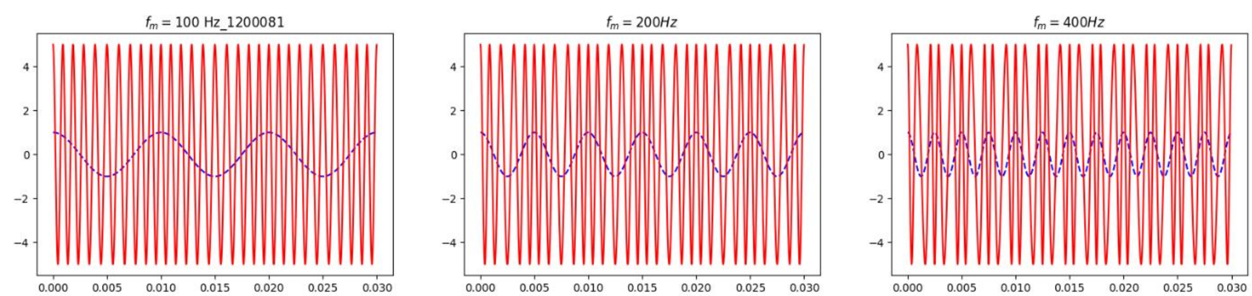


Figure 11.m(t),s(t) with vary value of fm

Changing the FM cycles in the message signal, as we can see in the previous images, affects the signal bandwidth. But the frequency deviation Δf remains constant.

3.2.FM in the Frequency Domain:

Massage signal in frequency domain:

M(f)= 5/2 [δ(f−100)+δ(f+100)]

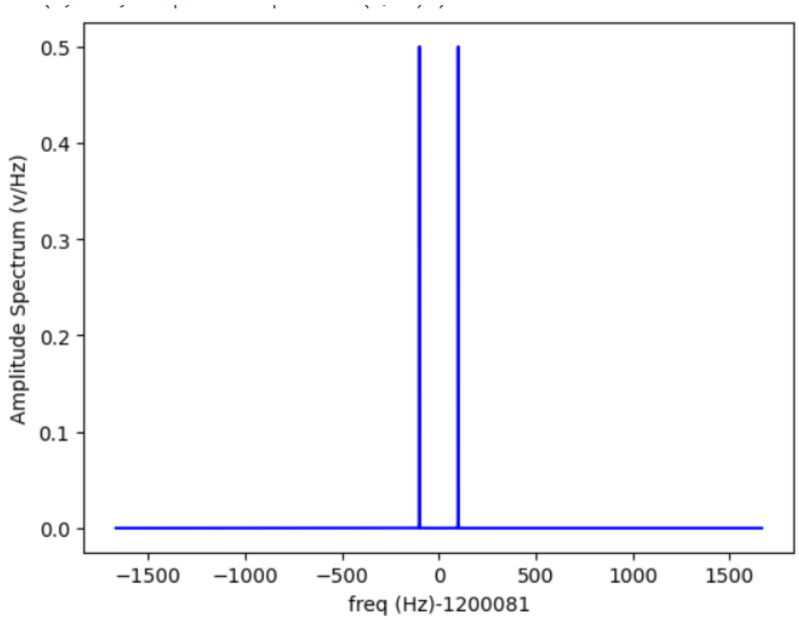


Figure 12.M(f)

From the drawing we notice that M (f) of the modulated signal m (t) = 5cos (2π × 100t) has two spectra with frequencies f = ± 100 Hz. This indicates that the signal is a pure cosine wave with a frequency of 100 Hz. The capacity of each line is 5/2.

- C(f)= 5/2 [δ(f−1000)+δ(f+1000)]

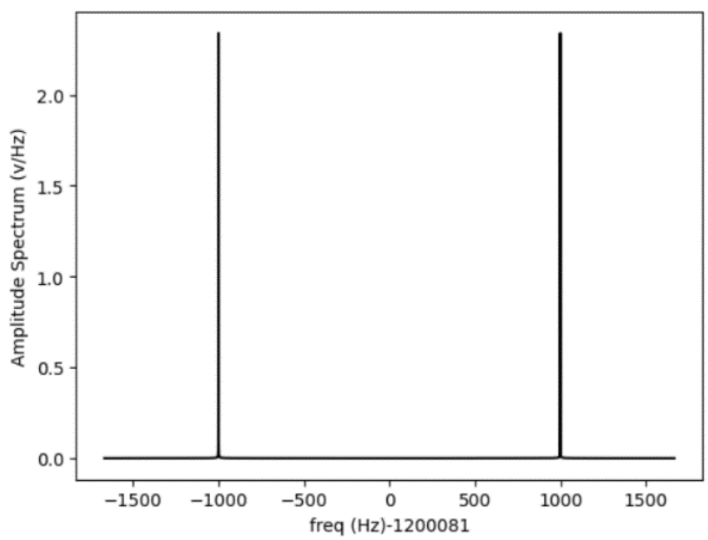


Figure 13.c(f)

From the drawing we notice that C (f) of the carrier signal C (t) = 5cos (2π × 1000t) has two spectra with frequencies f = ± 1000 Hz. This indicates that the signal is a pure cosine wave with a frequency of 100 Hz. The capacity of each line is 5/2.

- S(f):

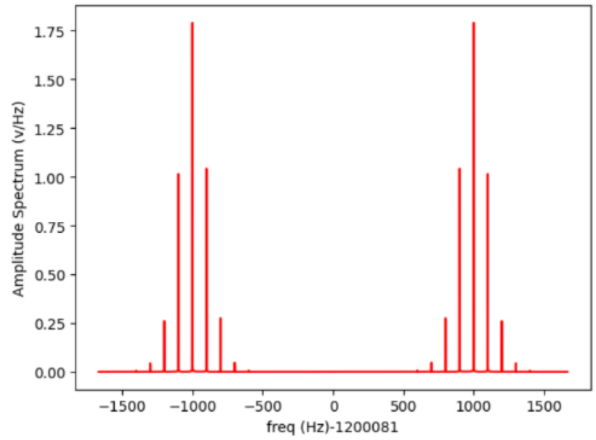


Figure 14.s(f)

The sideband frequencies can be expressed as fc +nfm and f c −nfm , where n is an integer

After we Change the value for Am=6,fm=100,Ac=4

We get this result in Time domain:

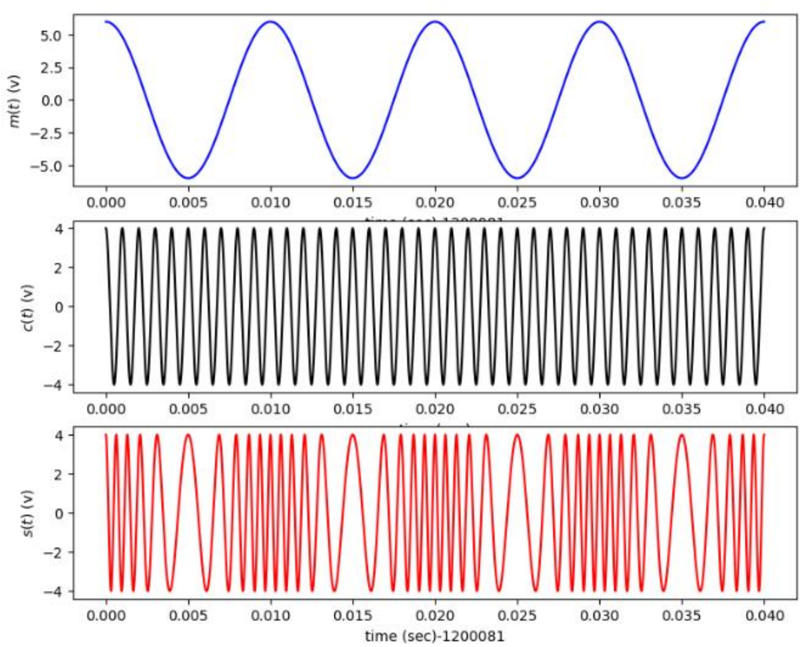


Figure 15.s(t),m(t) ,c(t) in time domain

Frequency domain:

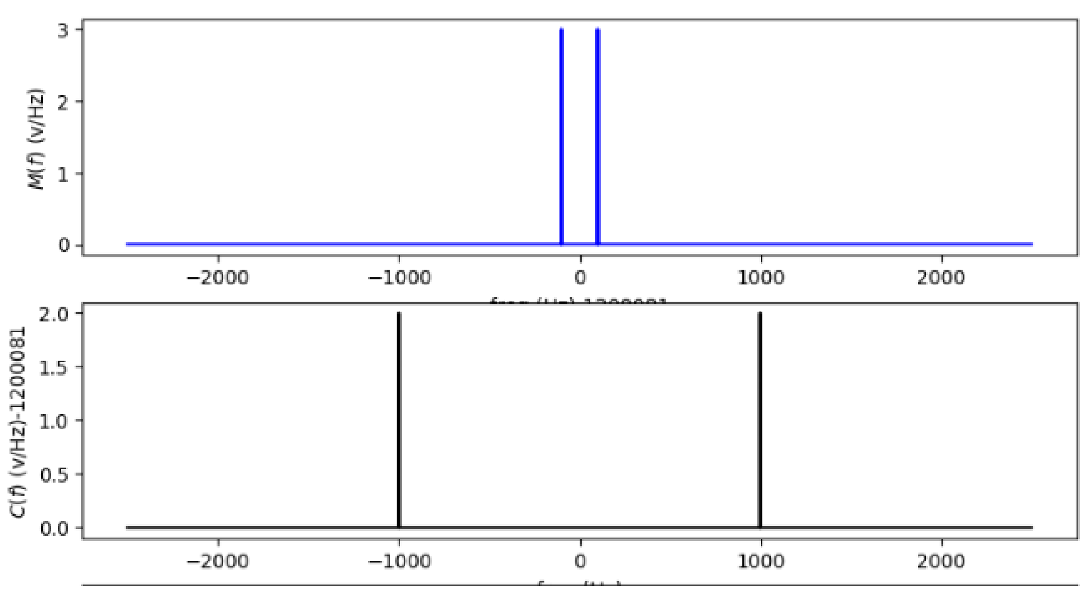


Figure 16 .m(f),c(f)

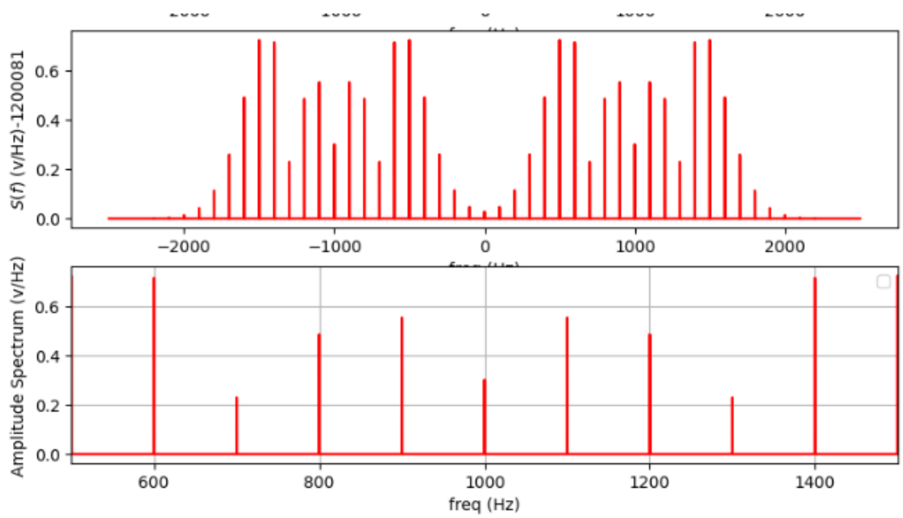


Figure 17.s(f)

3.3.Effect of The Frequency Modulation Index β on the Modulated Signal Bandwidth

First we consider a narrowband signal with $\beta=0.1$

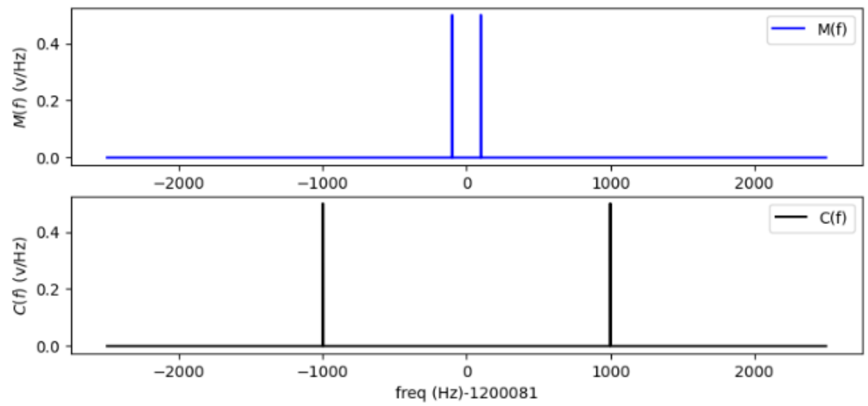


Figure 18.c(f),m(f) when β =0.1

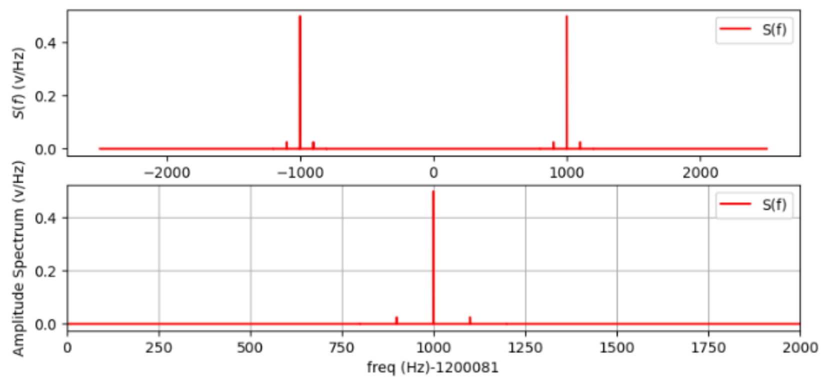


Figure 19.S(f) when β =0.1

When B<1, we have a narrow band FM, and it has a shape similar to a normal modulated AM signal, and this is what we notice in the last image of S(F) and the bandwidth of it = is comparable to that of AM modulation.

Let us now consider a wide-band FM signal with β=5.0

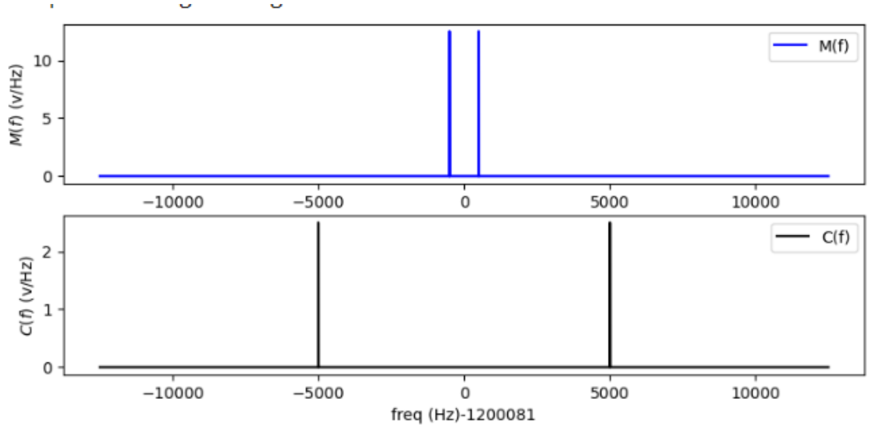


Figure 20.c(f),m(f) when β =5

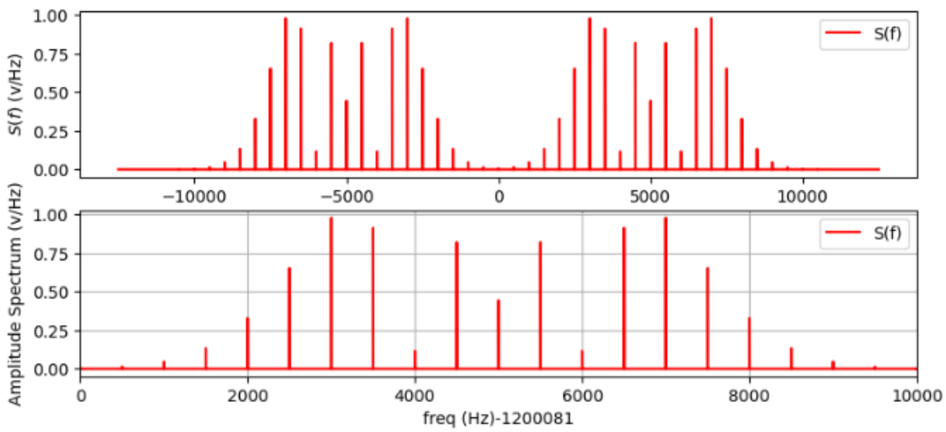


Figure 21.S(f) when β =5

when B>1 in FM, it results in wideband FM with a spectrum characterized by closely spaced sidebands, and the bandwidth is significantly larger than that of narrowband FM or standard AM.

The FM spectrum is greatly affected by the amplitude, frequency, and frequency sensitivity of the message signal. The change in modulation frequency causes divergence between the sidebands, which determines the spectral width. When changing the amplitude of the modulation wave, we will notice that the spectrum is expanded or contracted proportionately. Changing (kf) also leads to changing the width and height of the spectrum.

3.4.FM modulation zero-crossing

Here we will investigate whether the amplitude spectrum of s(t) consists of the sum of pulses located at integer multiples of fm. The amplitude of these pulses depends on the values of β and Jn(β). So we will choose a value for β that makes the amplitude δ(fc) of s(f) equal to zero. Based on Jn(β) being a first-order Bessel function of order n, the first zero (zero) of J0(β) occurs at β=2.41.

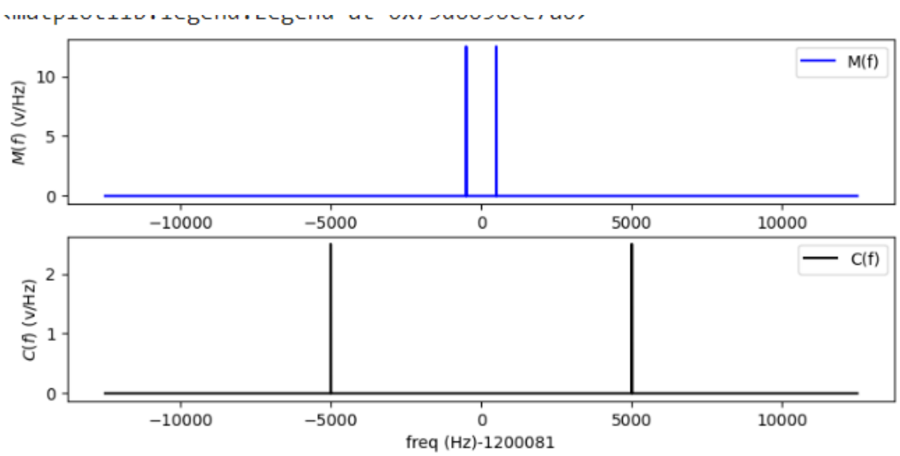


Figure 22.c(f),m(f)

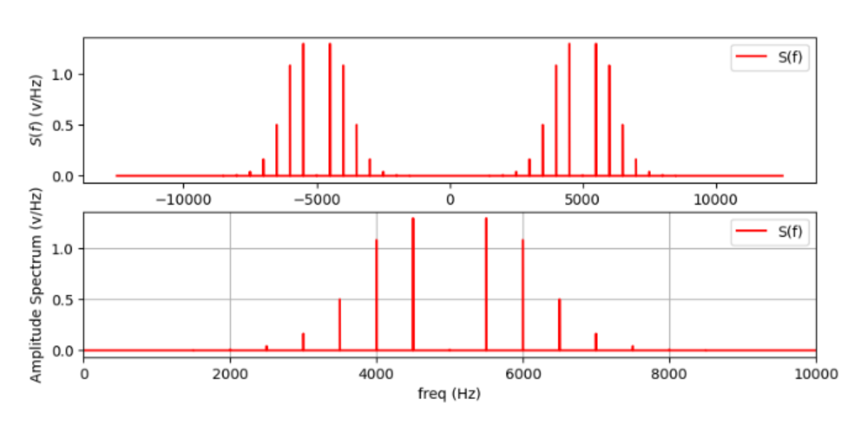


Figure 23.s(f)

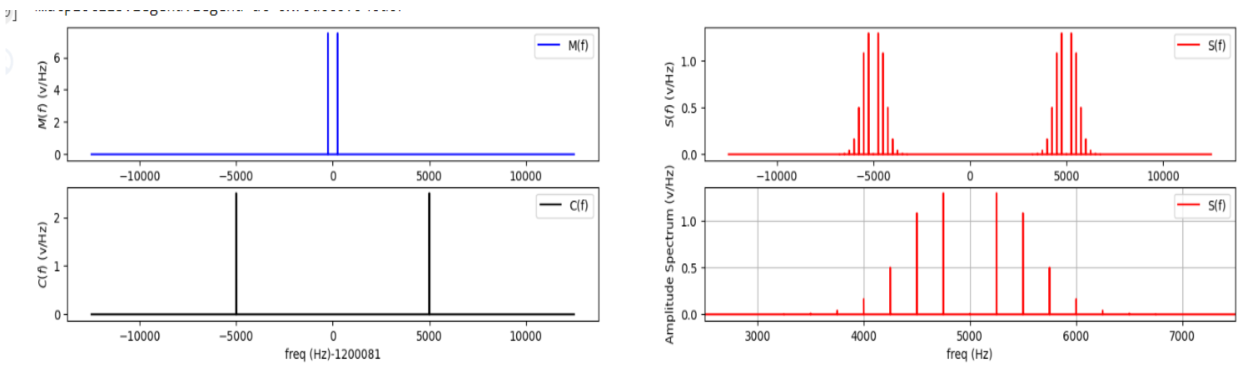
As observed from the s(f) plot, we obtained a zero at fc=5KHz . The frequency-sensitivity in this case is 48.2 Hz/Volt

Exercise 1:

To find other values of β in this case, we find them by considering higher order Bessel functions. When β = 5.53 or β = 8.65, the impulse amplitude at fc is also zero.

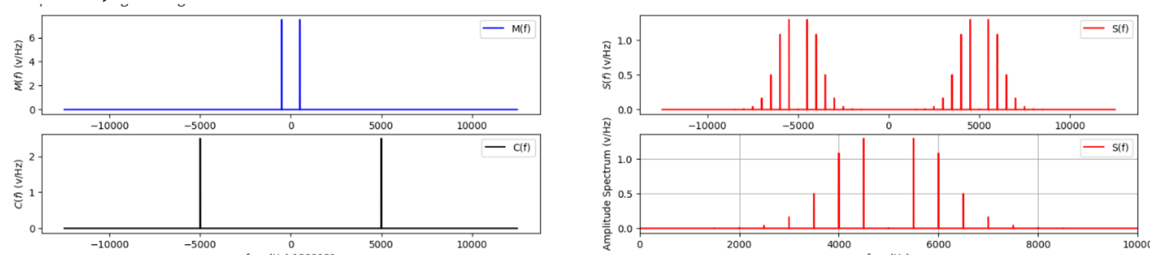
Exercise 2:

- When A_m=15,f_m=250Hz:



FM frequency-sensitivity = 40.166666666666664 Hz/Volt

- $A_m=15, f_m=500$Hz



FM frequency-sensitivity = 80.33333333333333 Hz/Volt

3.4.FM Demodulation:

The discriminator used here is a differentator followed by an envelope detector.

The output of the differentiator is $ds/dt=-2\pi A_c[f_c+k_f m(t)]\sin(2\pi f_c t+k_f\int_0^t m(\tau)d\tau)$

$Ds/dt=-2\pi A_c[f_c+k_f A_m\cos(2\pi f_m t)]\sin(2\pi f_c t+\beta\sin(2\pi f_m t))$

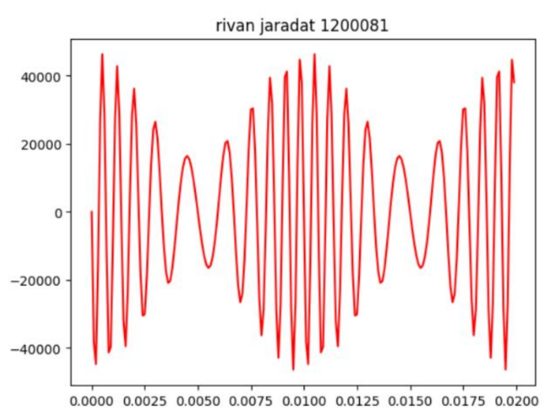


Figure 24.The differentiator output ds(t)/dt

The message can be retrieved using an envelope detector in a manner similar to that in AM signals. When the carrier frequency (fc) is high enough, this ensures that the carrier is not over-modulated, mirroring the approach used to demodulate an AM signal.

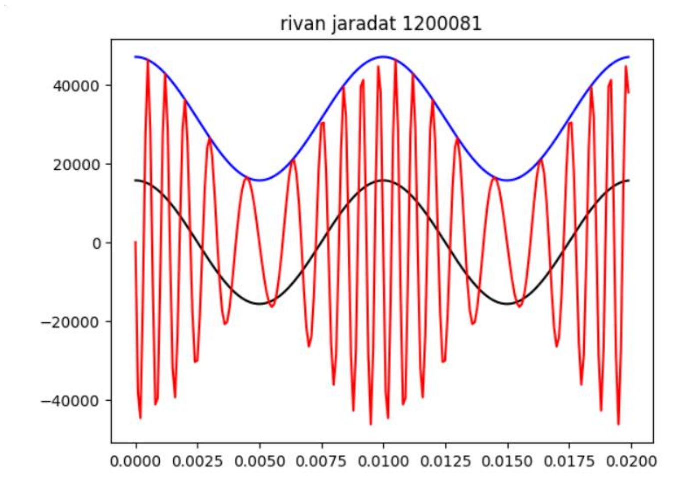


Figure 25.The signal after the envelope detector

3.5.FM of Square Wave

plot the FM signal when the modulating signal m(t) is a square wave.

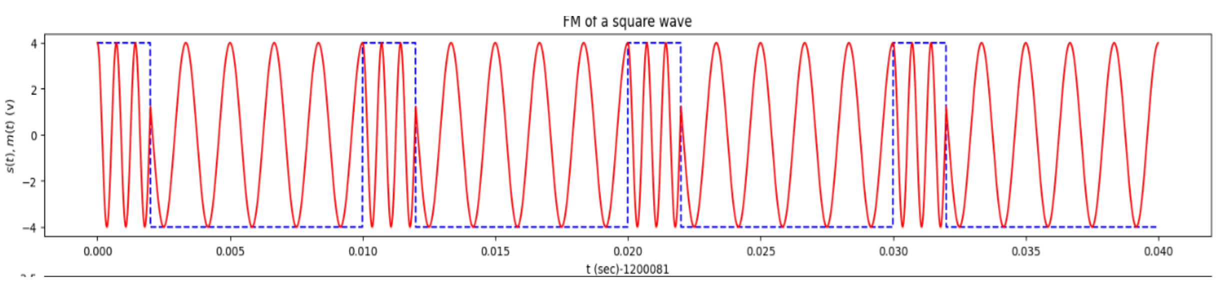


Figure 26. FM of a square wave

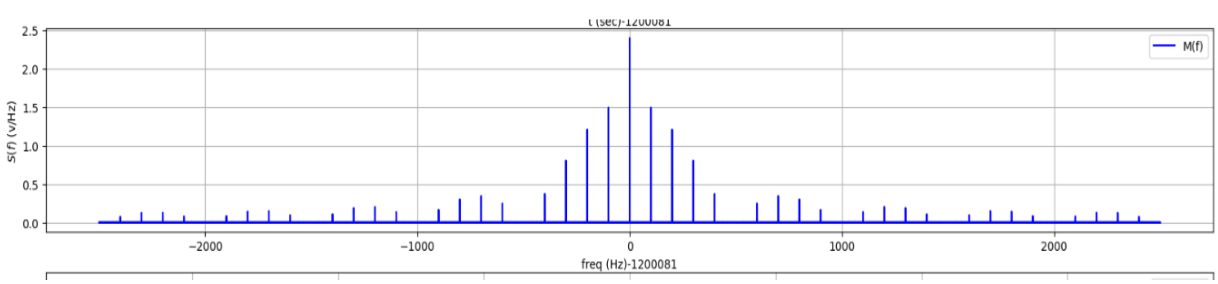


Figure 27.S(f) for a square wave

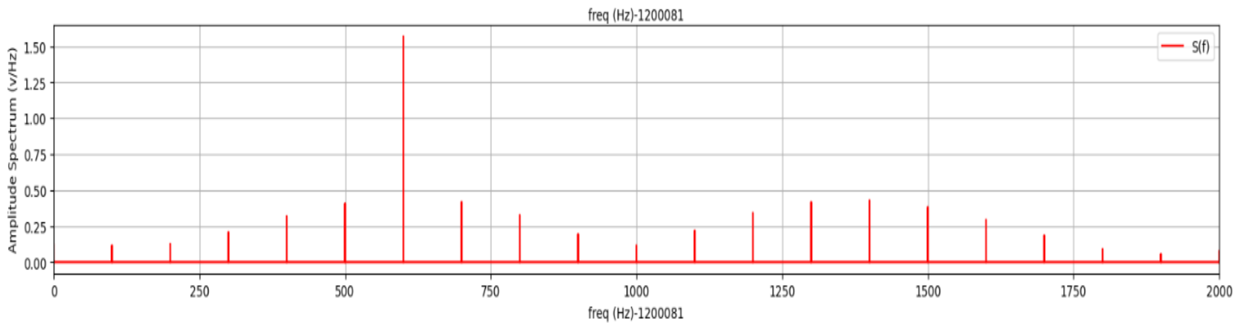


Figure 28. Amplitude spectrum for a square wave

Exercise: Vary the amplitude and duty cycle of the square message signal and observe the FM modulated signal in the time and frequency domain.

Am=2, d=0.1

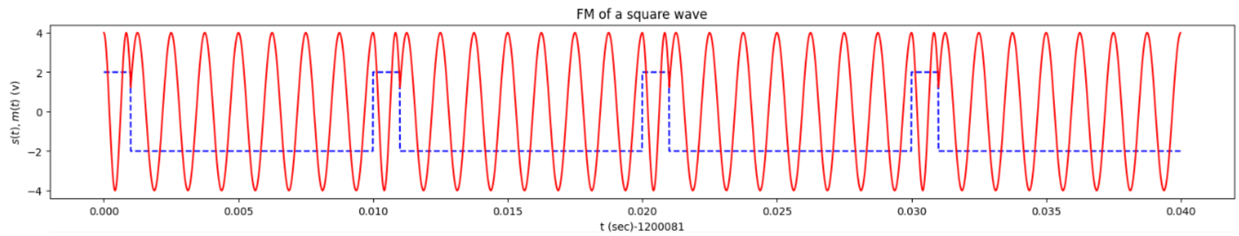


Figure 29.FM of a square wave

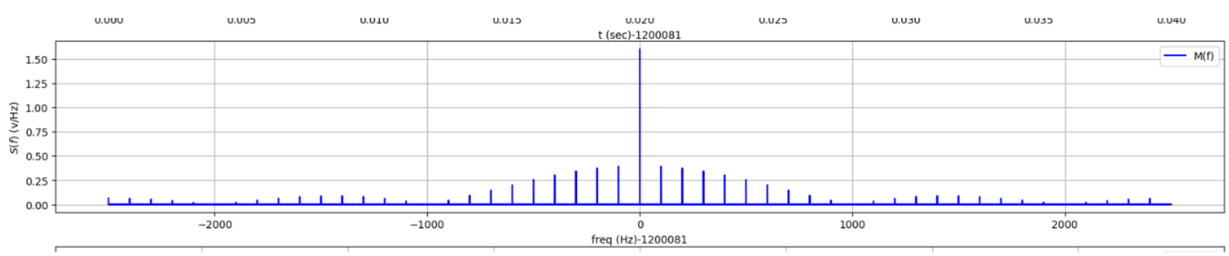


Figure 30. S(f) for a square wave

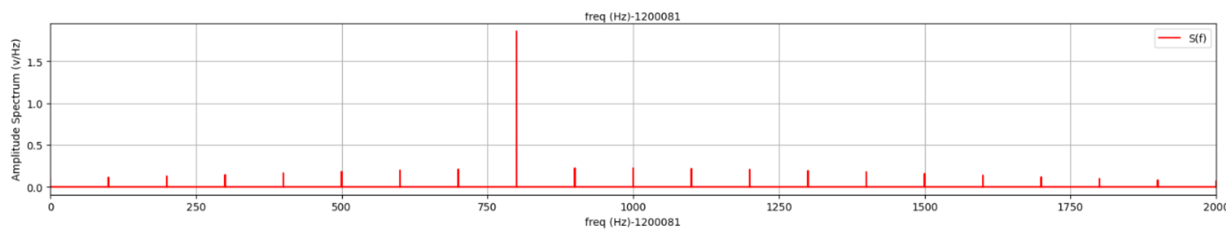


Figure 31.Amplitude spectrum for a square wave

When we reduced the value of Am = 2 to half, this led to a reduction in the amplitude in the FM signal s(t), and when changing the value of Du = 0.1, it affected (β) and potentially changed the spectral characteristics of s(t).

3.6. Phase Modulation:

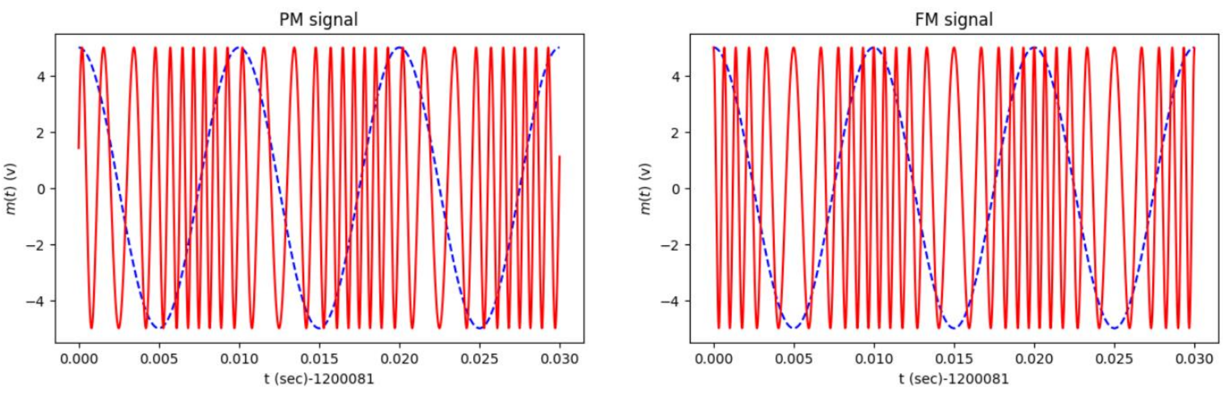


Figure 32.Comparison between FM & PM

Exercise : Vary Am and fm of the message signal and observe the PM and FM modulated signals.

Am=2,Fm=200

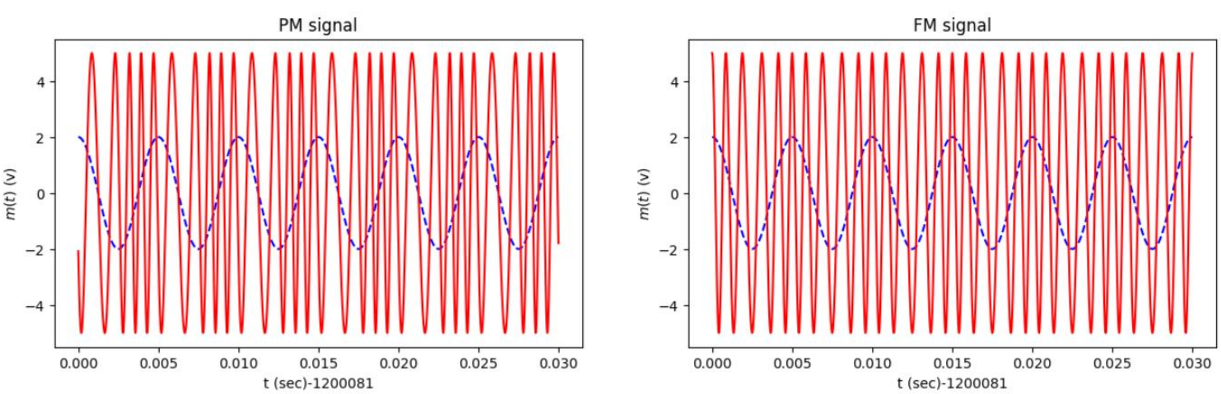


Figure 33.Comparison between FM & PM with Am=2 & fm=200

The FM modulated signal of a message m1(t) can be expressed as $s_{FM}(t)=A_c\cos(2\pi f_c t+k_f\int_0^t m_1(\tau)d\tau)$. And thus if $m_1(t)=dm(t)dt$, then $s_{PM}(t)=s_{FM}(t)$. In other words, to compute the Phase modulation of m(t), we can compute $m_1(t)=dm(t)dt$ and then apply m1(t) to the FM modulator.

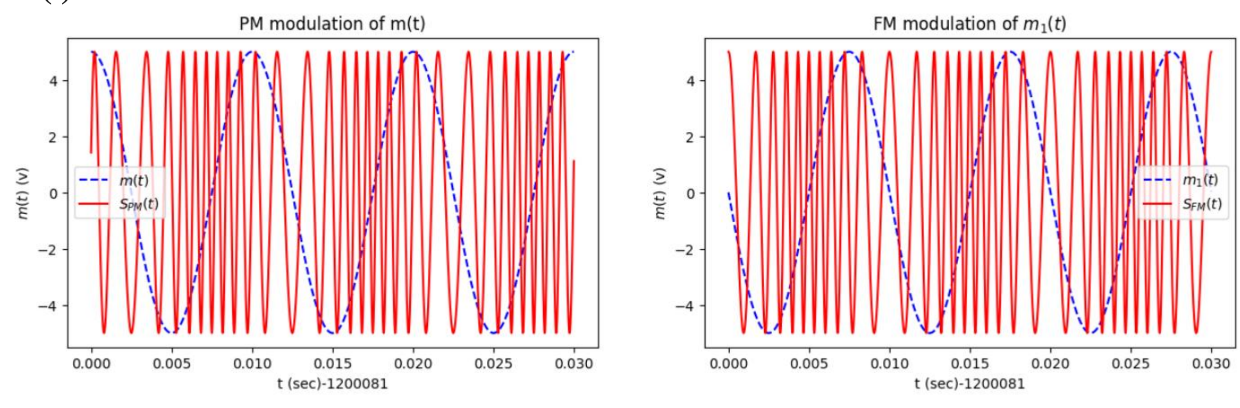


Figure 34.Comparison between FM & PM

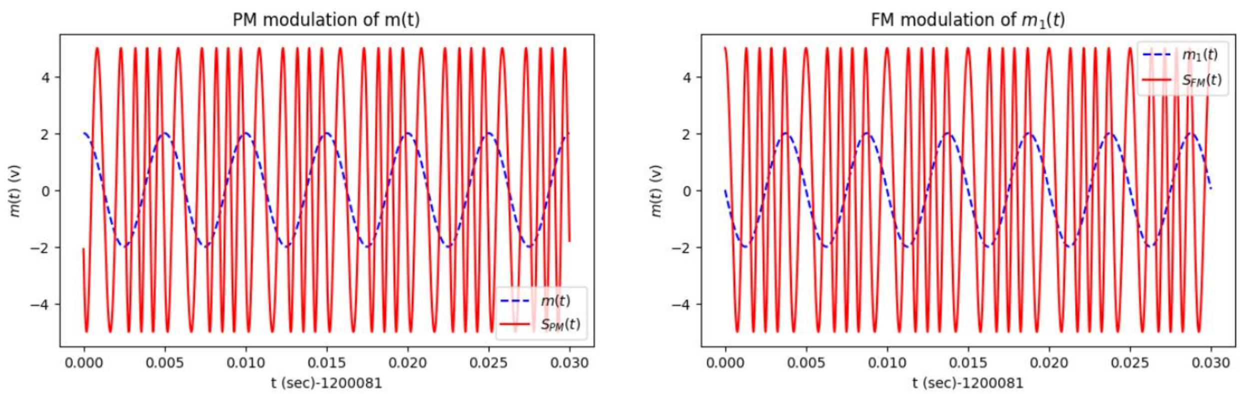


Figure 35.Comparison between FM & PM with Am=2 & fm=200

From the results we obtained, we notice that there is a match between the theoretical and practical aspects, and this indicates the success of the experiment, as changes in the parameters of the message signal, such as amplitude (Am) and frequency (fm), led to expected differences in the frequency deviation and spectrum width of the FM signal.; We proved the validity of the relationship between the theoretical and practical aspects through zero-crossing analysis of the modulation index, β, frequency sensitivity and modulation parameters.

4. conclusion:

The experiment was very successful as there was a thorough understanding of the theoretical and practical aspects of frequency modulation (FM) and phase modulation (PM). Through the practical side, there was a deeper understanding of the modulation indicators and their effect on the signal characteristics through the concepts of zero carrier crossing. The successful results also proved the validity of the theoretical principles. We became able to know the differences between FM and PM and what are the factors that affect them, so the experiment succeeded in achieving its goals.

5.References:

[1]. Admin. (2023, August 29). (1 DEC.2023).*Frequency modulation - definition, equation, applications, advantages*,. BYJUS. https://byjus.com/jee/frequency-modulation/

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