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Faculty of Engineering & Technology
Electrical & Computer Engineering Department

Communications Lab - ENEE4103

Report#2

Experiment NO. 5: Phase Modulation (PM)

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Abstract

This experiment employs laboratory equipment and the CASSY software to educate participants about phase modulation in the time and frequency domains. It covers concepts of PM modulator sensitivity and the fundamental characteristics of low-pass filters. Additionally, participants will explore the loop filter without pre-emphasis. The aim is to provide a comprehensive understanding of phase modulation and its practical applications

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1 Theory

1.1 Analog modulation

Analog modulation techniques include amplitude modulation, frequency modulation, and phase modulation. In other words, instead of encoding a signal in binary digits as with digital approaches, they work by modulating a continuous carrier wave.[1]

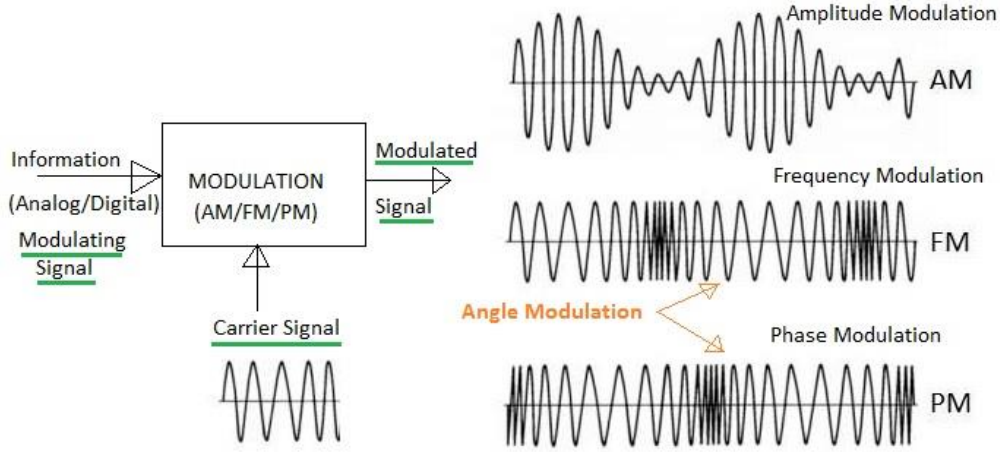

Figure 1.1: Analog Modulation [2]

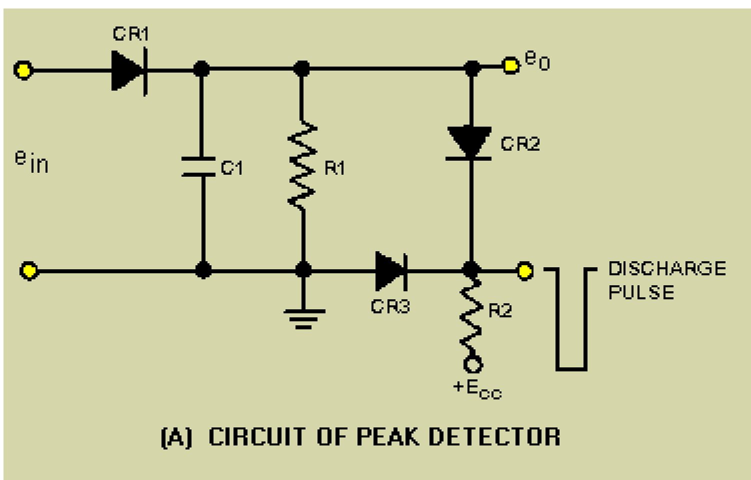

Figure 1.2: Phase Modulation Circuit Connection

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1.2 Frequecny Modulation

"Frequency modulation

In frequency modulation (FM), unlike AM, the amplitude of the carrier is kept constant, but its frequency is altered in accordance with variations in the audio signal being sent. This form of modulation was developed by the American electrical engineer Edwin H. Armstrong during the early 1930s in an effort to overcome interference and noise that affect AM radio reception. FM is less susceptible than AM to certain kinds of interference, such as that caused by thunderstorms and by random electrical currents from machinery and other related sources. These noise-producing signals affect the amplitude of a radio wave but not its frequency, and so an FM signal remains virtually unchanged.

FM is better adapted than AM to the transmission of stereophonic sound, audio signals for television programs, and long-distance telephone calls by microwave radio relay. Commercial FM broadcasting stations are assigned higher frequencies than are AM stations. The assigned frequencies, spaced 200 kHz apart, range from 88 to 108 MHz" [1]

1.3 Phase modulation

In PM transmission, the phase of the carrier signal is modulated to follow the changing voltage level (amplitude) of the modulating signal. The peak amplitude and frequency of the carrier signal remain constant, but as the amplitude of the information signal changes, the phase of the carrier changes correspondingly. It can be proved mathematically that PM is the same as FM with one difference. In FM, the instantaneous change in the carrier frequency is proportional to the amplitude of the modulating signal; in PM the instantaneous change in the carrier frequency is proportional to the derivative of the amplitude of the modulating signal.

PM is normally implemented by using a voltage-controlled oscillator along with a derivative. The frequency of the oscillator changes according to the derivative of the input voltage, which is the amplitude of the modulating signal.[3]

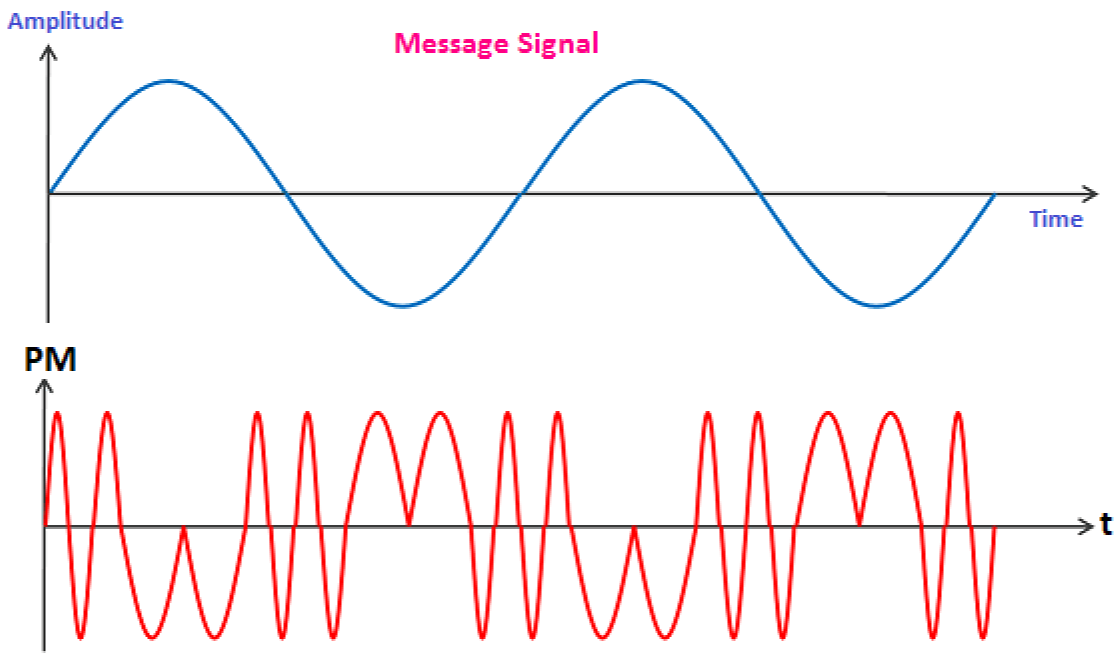

Figure 1.3: Phase Modulation [4]

1.3.1 Modulation

"Modulation refers to converting the information signal to a suitable form of transmission. Here, the incoming message signal is converted to radio waves, which is a suitable mode of transmission for the communication system.

The modulation process of PM is similar to the FM modulation process except for the integrator. FM requires an integrator before the modulated signal is applied to the balanced modulator. The integrator block in FM is present before the balance modulator block. But in PM modulation, no integrator block is required. The block diagram of the PM modulator is shown below. "

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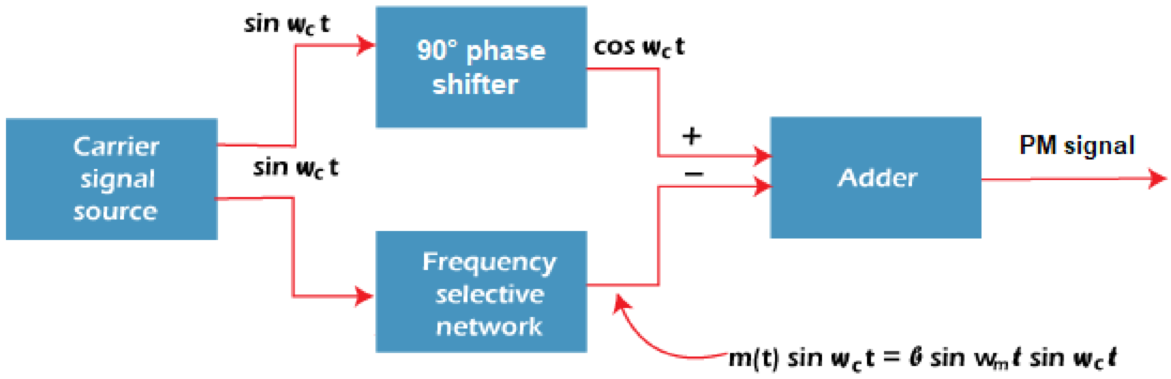

Figure 1.4: The block diagram of the PM Modulator [4]

A carrier signal source, a balance modulator, an adder, and a 90 degree phase shifter make up the circuit. A carrier sine wave with a carrier frequency of c is produced by the source of the carrier signal. The carrier signal sinct is changed to cosct, the carrier with a 90 ° phase shift, by the 90 degree phase shifter. By combining the message with the carrier signal sine, a balance modulator creates a double sideband amplitude modulated signal. The output signal is typically a carrier signal that has been suppressed. The phase shifter and balance modulator outputs are delivered to the adder, which then adds the two outputs. Phase modulated signal is created by adding the carrier with a 90° phase shift to the balanced modulator's output.[4]

The instantaneous phase $2\pi fi(t) = \frac{d\theta}{dt} = \frac{d}{dt}[2\pi fc(t) + \theta c(t)] = 2\pi fc + \frac{d\theta c(t)}{dt}$

Where the phase and frequency variances are denoted by θc(t) and dθc(t)/dt, respectively. PM develops when the phase deviation is inversely proportional to the message signal, while FM happens when the frequency deviation is inversely proportional to the message signal. Consequently, the modulated signal for PM is

$$\theta i(t) = 2\pi fct + kp\, m(t)$$

The modulator's phase sensitivity is represented by the constant kp and the terms 2fct respectively. It makes the convenient assumption that the angle of the unmodulated carrier is zero at time t = 0. Thus, the time domain description of the PM wave s(t) is

$$S(t) = Ac \cos 2\pi fc\, t + kp\, m(t)$$

1.3.2 Phase Demodulated

The process of demodulation involves restoring the original signal. The recipient is doing its job. It restores the signal to its initial state. The demodulation of FM and the demodulation of PM are connected. Let y(t) be the FM demodulator's output. The output of the FM demodulator is directly proportional to the modulated signal.[4]

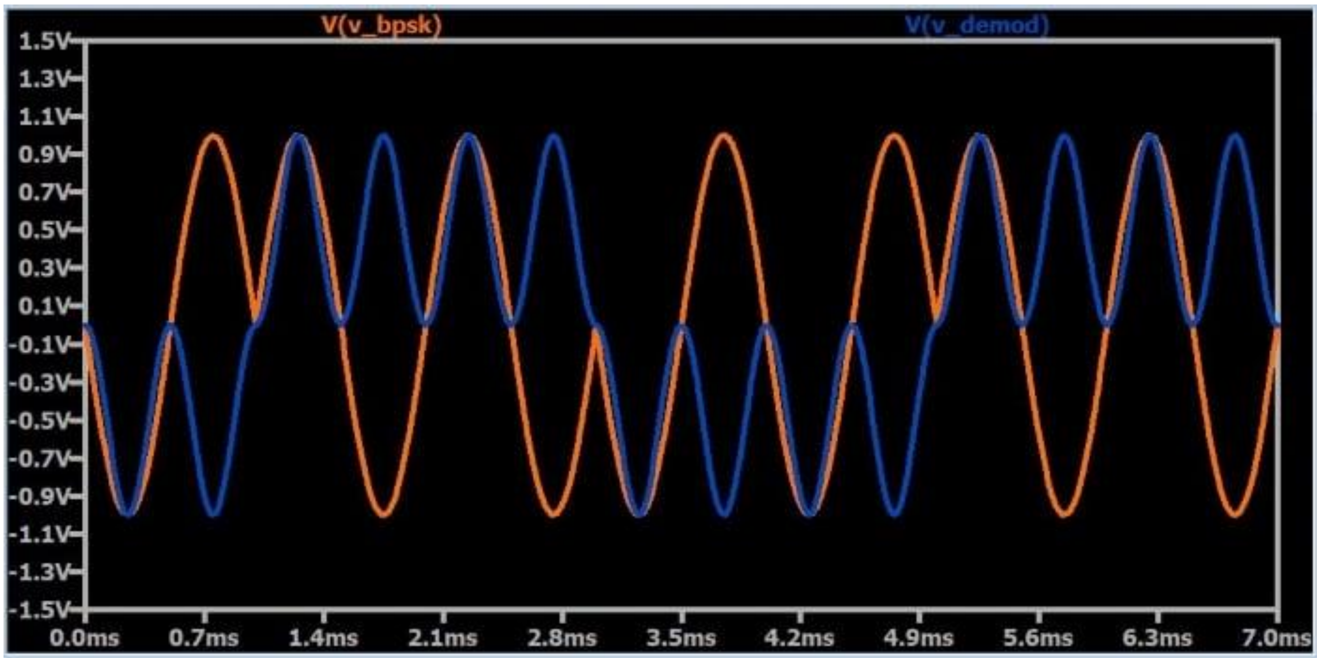

Figure 1.5: Demodulation Signals [5]

$m(t) \propto y(t)$ W here m(t) is the modulated signal , $m(t) \propto \theta i(t)$ The message is also proportional to the phase angle of the modulating system. It is the condition for the phase modulated signal.

$y(t) \propto \frac{d\theta}{dt}$ $y(t) = k\frac{d\theta}{dt}$

The proportionality symbol is never used in place of a constant. K is the proportionality constant

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2 Procedure, Results and Discussion

2.1 Part One: PM Modulation

Section 1:

The function generator selection was set to a pulse train with the parameters fm = 1 kHz, VSS = 2 V for the pulse amplitude,

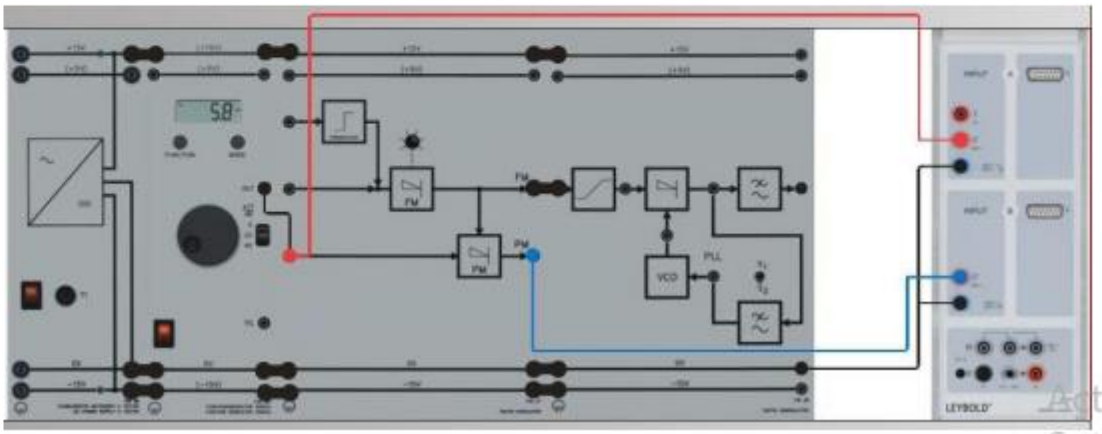


Figure 2.1: Function Generator Connections

time domain?

The signal was plotted in the frequency domain as shown in Figure 2.2

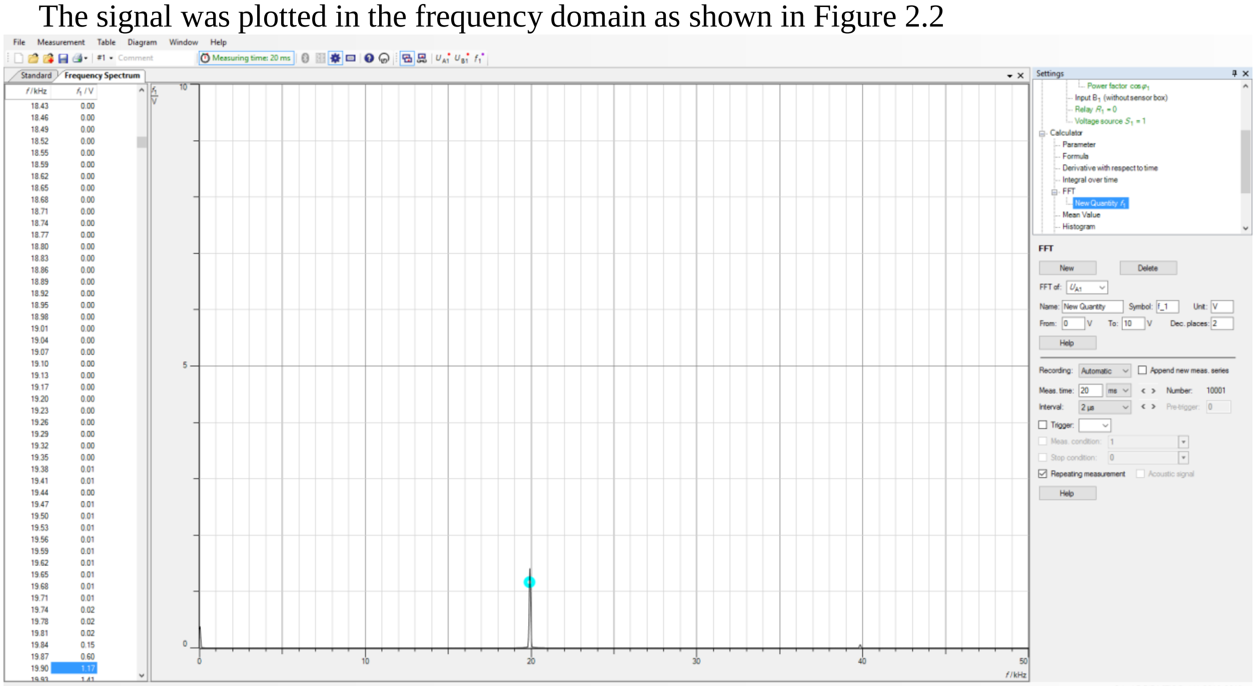


Figure 2.2: The Signal in Frequency Domain when fc=20 KHz

m(t) and s(t) in time and freq?

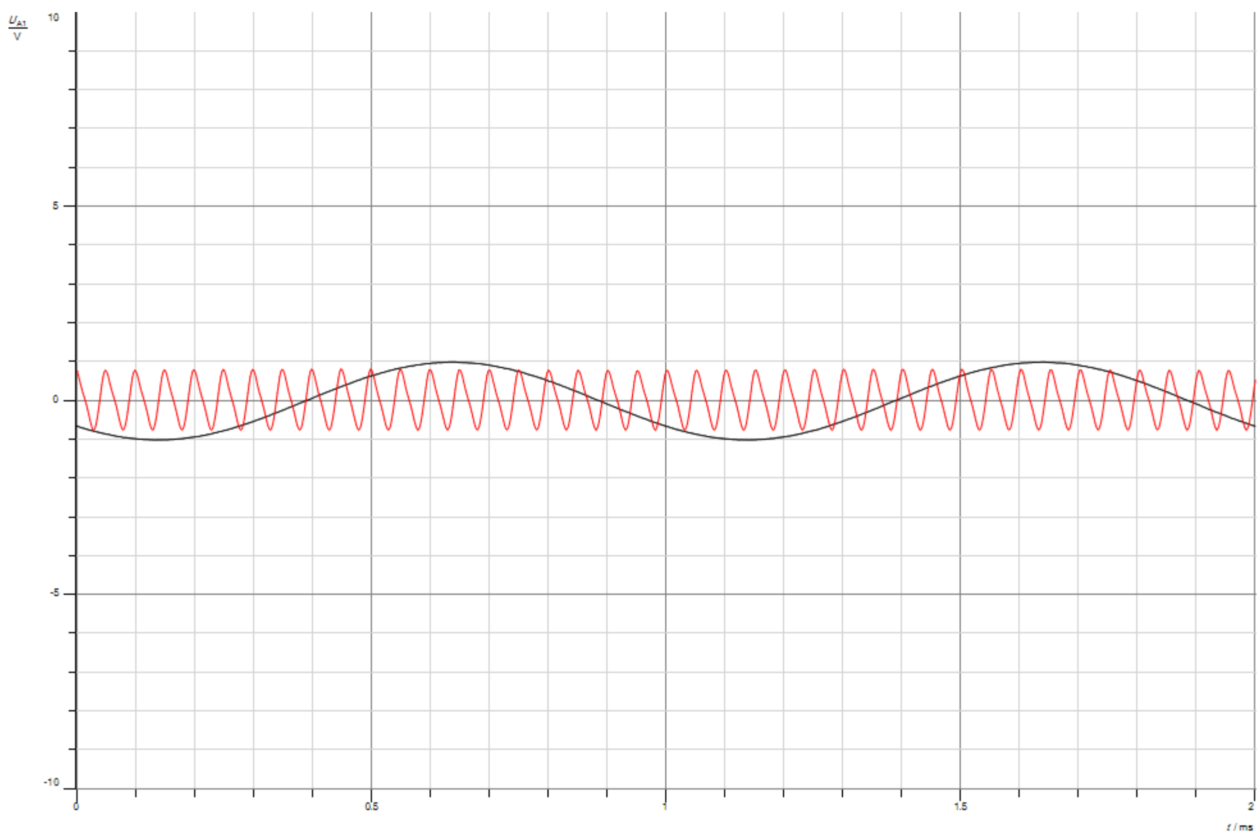
Because the PM range is enabled (from -1 to 1), the modulated signal does not change in relation to the message amplitude. However, FM falls between (-10 to 10). This explains why the modifications have no impact on amplitude.

Section 2:

2.1 The Characteristics of the PM Modulator

In this section, the modulator sensitivity constant, kp, expressed in °/V, must be determined. A carrier signal at a frequency of 20 kHz will be used to modulate a DC-signal message signal that starts at -1V. It is necessary to load the PM_TD.labx example from CASSY Lab 2.

The phase shift between the carrier oscillations of the FM and PM output, t (s), will then be calculated. The carrier frequency will once again be measured as the DC voltage is increased in 0.2V steps. The given table will include a record of the gathered data.



calculate delta t = tout -tin

Figure 2.3: The modulated signal in the time domain

- The message signal
- The Modulated signal

In PM, the modulating signal's amplitude causes a proportional phase shift in the carrier signal. This implies that at any instant in time, the amplitude of the modulating signal is directly proportional to the instantaneous phase of the carrier wave. The modulating signal's strength or amplitude has no bearing on the phase modulation.

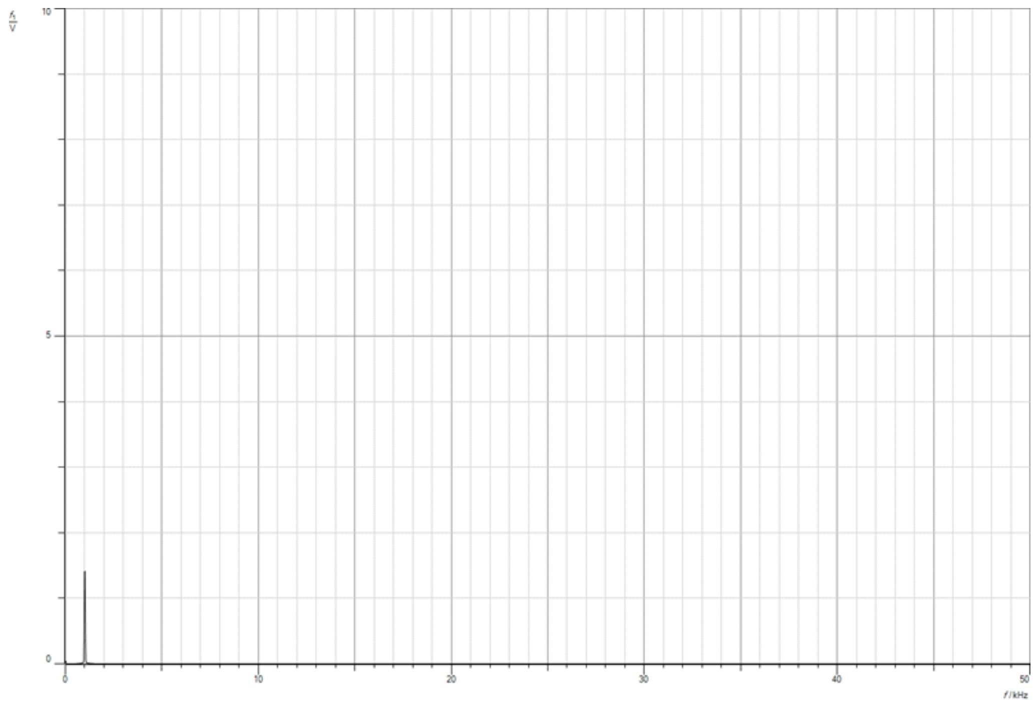


Figure 2.4: The modulated Signal in The frequency domain

The frequency variation in PM and the modulating signal's frequency have a nonlinear connection. The carrier signal's frequency deviation could change significantly depending on even small changes in the frequency of the modulating signal. This feature sets PM apart from other modulation methods like frequency modulation (FM), where the frequency variation is inversely proportional to the modulating signal's amplitude.

Message Voltage	Δt	$\Delta\theta$	Message Voltage	Δt	$\Delta\theta$
-1	6µ	43.2	**0.2**	2 µ	14.4
-0.8	5 µ	36	**0.4**	1 µ	7.2
-0.6	5 µ	36	**0.6**	1 µ	7.2
-0.4	5 µ	36	**0.8**	3 µ	21.6
-0.2	4 µ	28.8	**1**	5 µ	36
0	3 µ	21.6			

Table 2.1: The Relation between Message DC and carrier Frequency to represent Kp

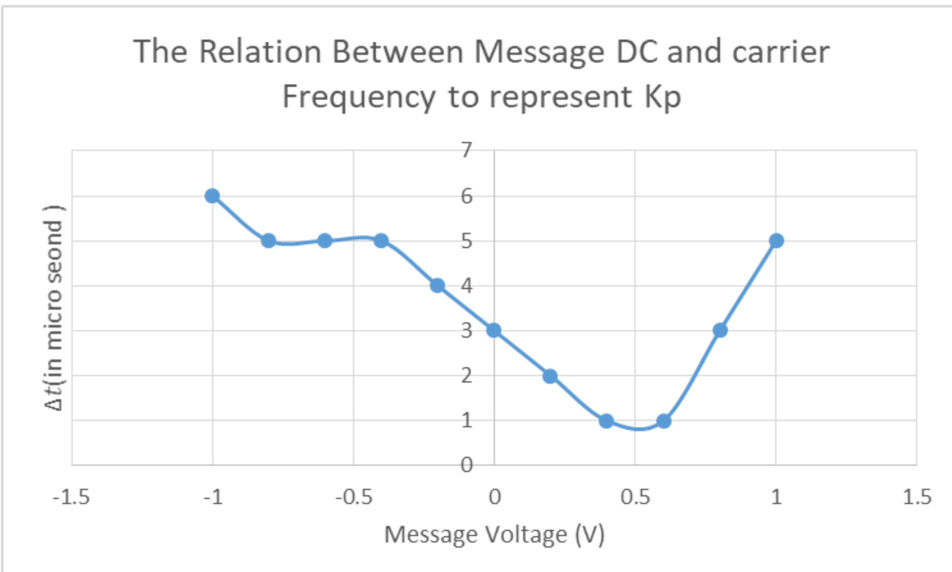


Figure 2.5: The modulated Signal in The frequency domain

During the laboratory experiment, it was observed that in the rated voltage range (1 to zero), PM is found to be led by FM on the left side of Table 2.1. Conversely, on the right side, as the message signal is altered, FM is seen to lead PM.

$$\Delta\theta = \frac{\Delta t}{Tc}360 = \Delta t * fc * 360 = 6\mu * 20K * 360 = 43.2$$

kp = slope = ?

2.2 Displaying the PM signal spectrum:

The modulated signal spectrum was plotted using the Cassy Lab setup, maintaining the same kit arrangement. A sinusoidal signal with VSS = 2V and fm = 300Hz was employed as the message signal, ensuring a 0V DC offset. A picture of the resulting spectrum, with the x-axis range appropriately adjusted for clarity, was taken. Similarly, the measurement was repeated using a message signal VSS = 2V and fm = 200Hz. The modulated signal spectrum was plotted using the Cassy Lab, and a picture of the impulses was taken, again with the x-axis range adjusted suitably..

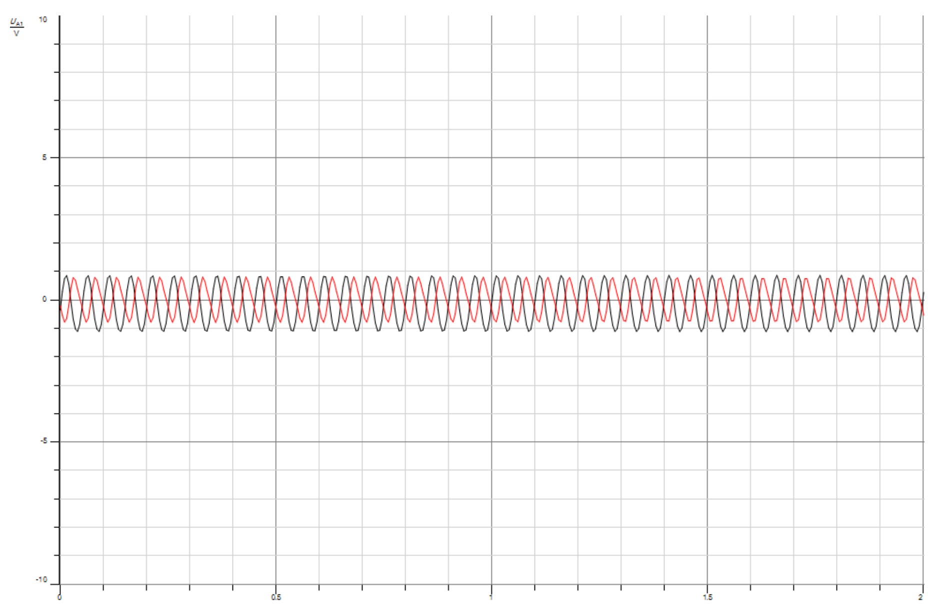


Figure 2.2.1:Modualted Signal in the time domain with fm=300Hz

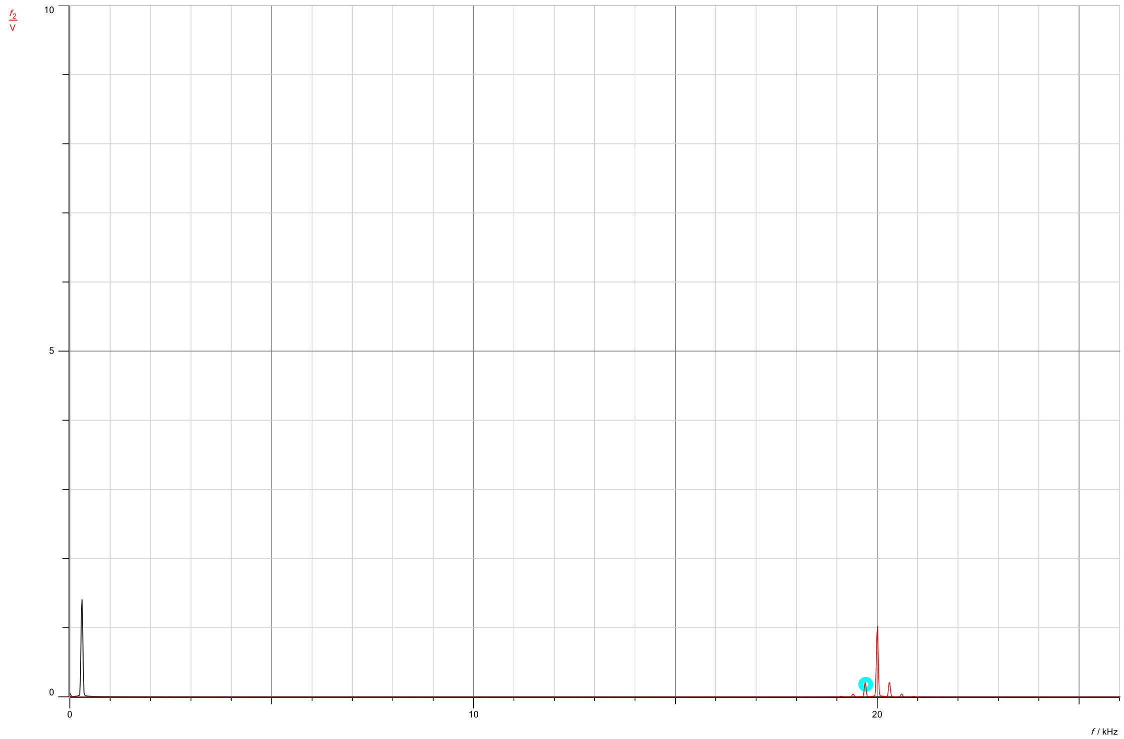


Figure 2.2.2:Modualted Signal in the Frequency domain with fm=300Hz

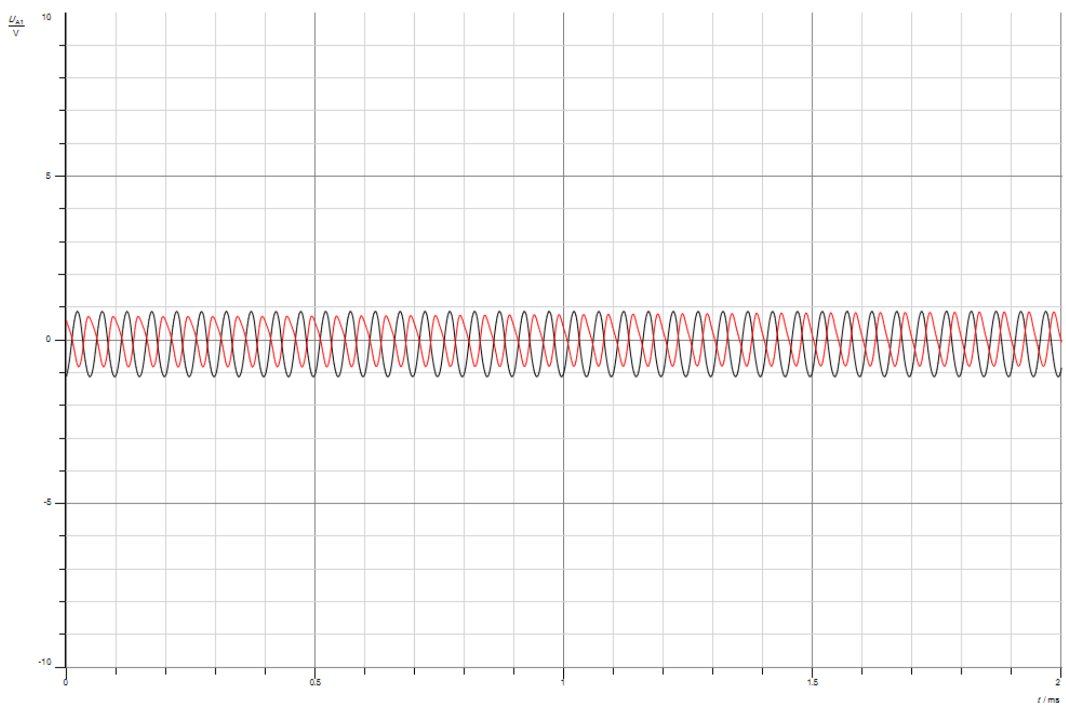


Figure 2.2.3:Modualted Signal in the Time domain with fm=200Hz

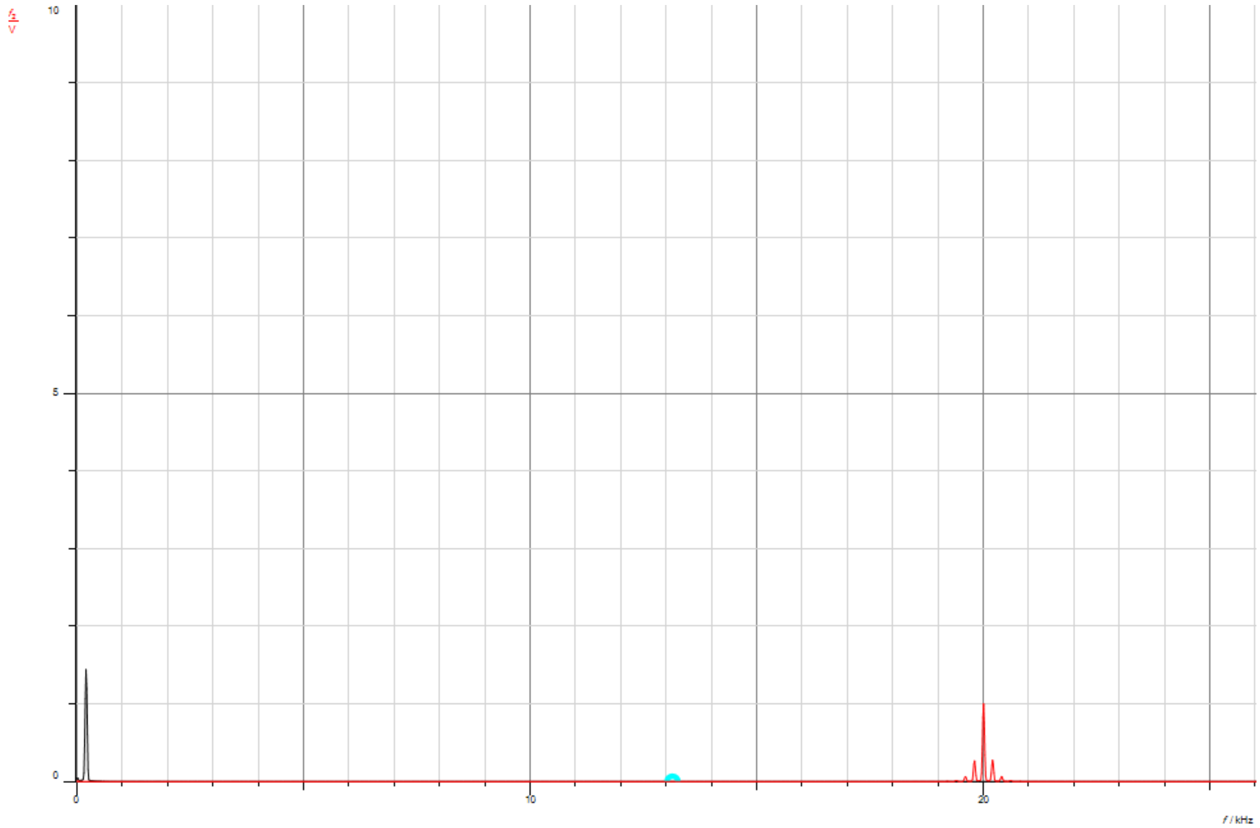


Figure 2.2.4:Modualted Signal in the Frequency domain with
fm=200Hz

Phase modulation (PM) is influenced by the frequency of the message signal. Increasing the message signal frequency causes the carrier signal's phase to change more rapidly, resulting in a compressed waveform with shorter intervals between phase changes. Decreasing the message signal frequency leads to a slower change in the carrier signal's phase, creating a stretched waveform with longer intervals between phase changes. In PM, the frequency of the message signal directly affects the rate of phase change in the carrier signal, influencing the overall shape and timing of the modulated waveform. The decrease in message signal frequency from 300 Hz to 200 Hz results in a slower rate of phase change in the carrier signal. This leads to longer intervals between phase changes in both the frequency and time domains. In the frequency domain, the waveform appears stretched out, while in the time domain, the phase changes occur more gradually, creating a slower modulation effect.

The spectral properties of Phase Modulation (PM) and Frequency Modulation (FM) differ. In PM, the amplitude of the message signal directly modulates the phase of the carrier signal. This results in sidebands dispersed around the carrier frequency, whose amplitude is affected by the strength and frequency content of the message signal. In FM, the frequency of the carrier signal is modulated in proportion to the strength of the message signal. The carrier frequency and sidebands above and below it make up the final spectrum, with the sideband amplitudes being determined by the modulation index and frequency deviation. While sidebands are used in both approaches, the modulation mechanisms (phase variation in PM and frequency variation in FM) produce different spectral characteristics.

2.3 Part 2:PM Demodulated

Section 1: Time domain PM demodulated signal.

A sinusoidal message signal m(t) with a frequency of 500 Hz and an amplitude of 2 V (VSS = 2V) was utilized. The loop filter on the PM demodulator was set to two. Subsequently, the message and demodulated signals were plotted and examined

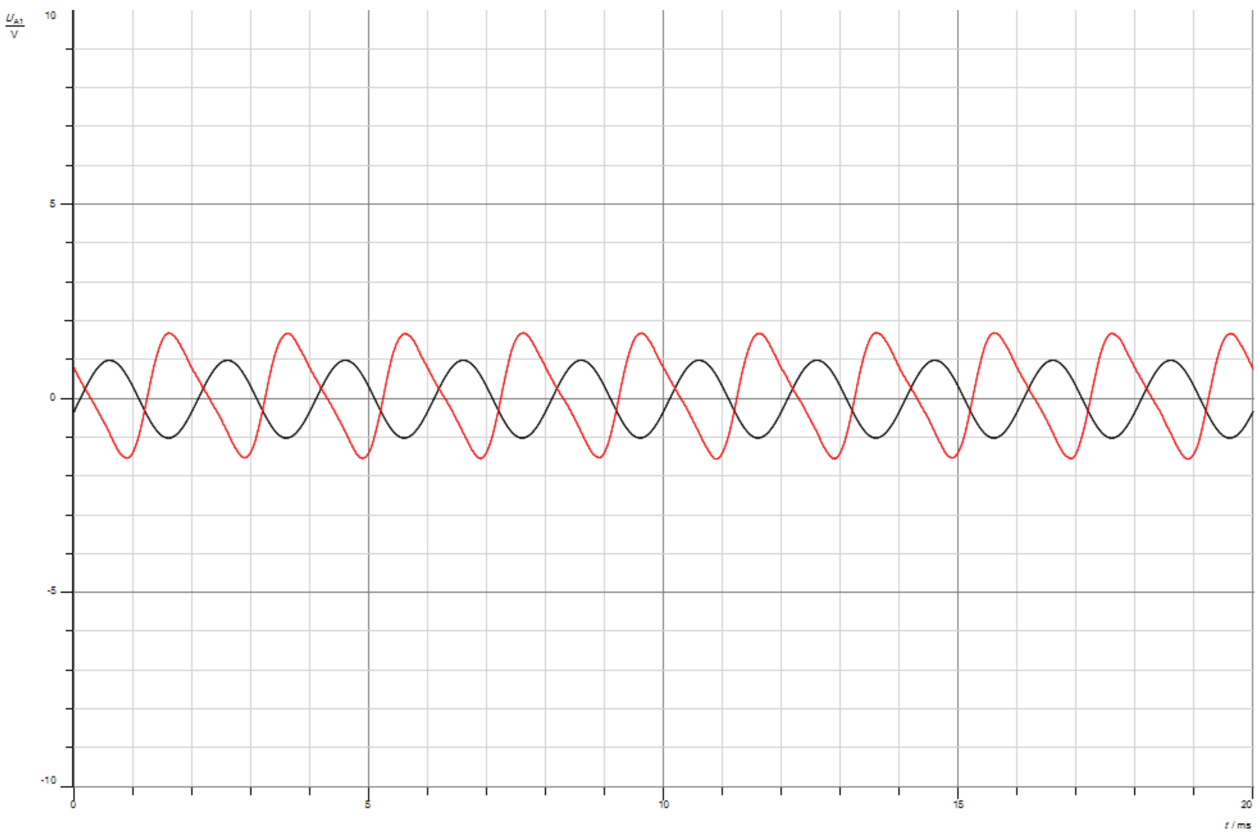


Figure 2.3.1: The Modulated signal

Yes

The Phase-Locked Loop (PLL) demodulator is capable of demodulating a Phase Modulation (PM) signal by comparing the phase of the input signal with a reference signal generated by a Voltage-Controlled Oscillator (VCO). The resulting phase difference is converted into an error signal and filtered by a loop filter to control the VCO's frequency. This process ensures the accurate recovery of the original message signal from the PM signal. The PLL demodulator is widely used in communication systems for PM signal demodulation.

2.3 PM Demodulation

- **Section 2: Studying the effect of the receiver loop filter**

The receiver for this experiment is implemented to allow the use of two receiver loop filters. Each filter represents a low-pass filter with a special gain-bandwidth characteristic. The objective of this section is to compare the message signal with the demodulated signal by varying the gain of the loop filter between the two filters. The components are then assembled as shown below.

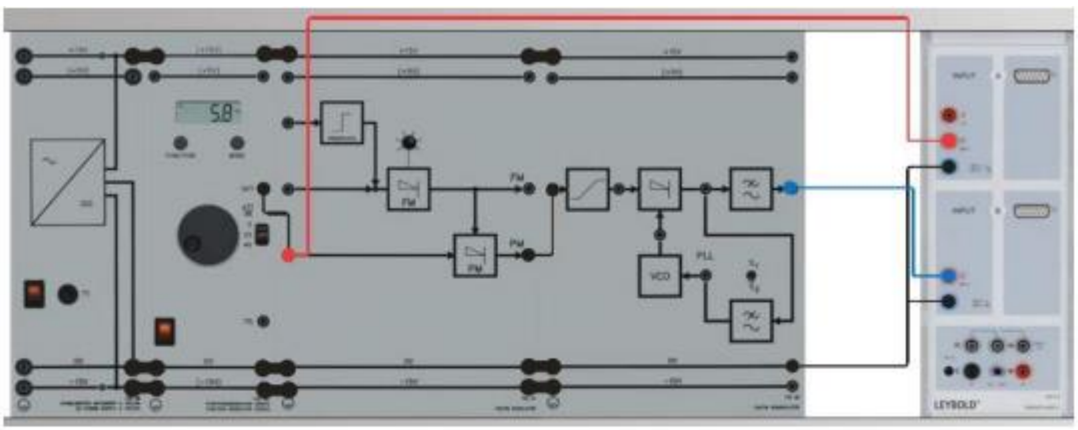


Figure 2.3.2: The effect of the receiver loop filter

Without the Pre-emphasis						
Message Frequency (Hz)	**500**	**1000**	**2000**	**3000**	**4000**	**5000**
Ad using τ1 filter	8.98/1.43	3.45/1.37	1.04/1.44	0.44/1.39	0.29/1.41	0.14/1.41
Ad using τ2 filter	2.08/1.43	1.53/1.37	0.97/1.44	0.55/1.39	0.31/1.41	0.17/1.41

Table 2.2: Loop filters τ1 and τ2 without pre-emphasis

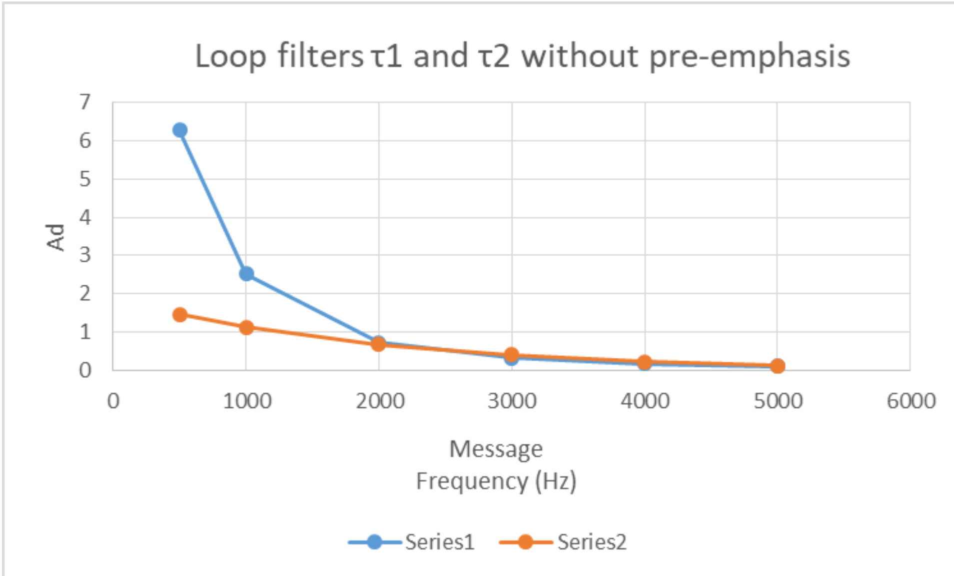


Figure 2.3.2.2: Loop filters τ1 and τ2 without pre-emphasis

- *τ1*
- *τ 2*

The non-ideal nature of this filter leads to a distinct variation in the second harmonic as the gain Ad is modified. In an ideal scenario, all harmonics would exhibit uniform levels and lengths.

Pre-emphasis in PM modulation involves applying a high-pass filter to boost the higher-frequency components of the modulating signal. It compensates for transmission limitations, improves the signal-to-noise ratio, and enhances system performance. At the receiver end, a de-emphasis filter is used to restore the original frequency balance by attenuating the higher-frequency components. This technique helps achieve better transmission quality and resistance to noise and distortion in PM modulation systems.

3 Conclusion

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In this comprehensive experiment, participants utilized lab kits and the powerful CASSY software to delve into the intricacies of phase modulation and demodulation methods in both the time and frequency domains. The experiment encompassed an in-depth exploration of PM modulator sensitivity, enabling participants to gain valuable insights into its impact. Additionally, participants familiarized themselves with the characteristics of low pass filters, a fundamental component in signal processing. By transforming theoretical knowledge into practical applications, participants acquired a profound understanding of phase modulation and its real-world implications. The experiment served as a gateway to mastering phase modulation techniques and its versatile applications.

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4 References

[1] " https://engineerscommunity.com/t/analog-modulation/5622 ".

[2] "https://www.test-and-measurement-world.com/Terminology/Difference-between-amplitude-modulation-and-angle-modulation.html "

[3] " https://www.accessengineeringlibrary.com/binary/mheaeworks/d2492ca10ad2b247/0ea99267e3df090b7335b49be8794340f9610f10bc7d86a157faef663d8ff5cf/analog-transmission.pdf?implicit-login=true "

[4] " https://www.javatpoint.com/phase-modulation"

[5] "https://www.allaboutcircuits.com/textbook/radio-frequency-analysis-design/radio-frequency-demodulation/how-to-demodulate-digital-phase-modulation/"

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