جامعة بيرزيت

BIRZEIT UNIVERSITY

Department of Electrical & Computer Engineering

ENEE4113 - Communications Laboratory

Experiment #4
Frequency Modulation

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Abstract

In this experiment, we study the PM modulation, demodulatiom various techniques, PM spectrum, PM characteristic and how to derive the modulation index. We also study the effect of freqeuncy on modulation spectrum, and the effect of the differnt PLL Loop filter on the demodulated signal.

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1 Theory

1.1 Modulation Scheme

Phase modulation is a part of angle modulation, angle modulation is a technique with constant carrier amplitude and varying phase or time derivative of phase. an FM signal can be expressed as:

$$s(t) = A_c \cos(\omega_c t + k_p \times m(t)) \tag{1}$$

- A_c is the carrier amplitude
- ω_c is the carrier frequency
- k_p is the modulation sensitivity
- $m(t)$ is the message signal

The instantaneous freqeuncy of the PM Singal is:

$$f_i = f_c + k_p \times m(t) \tag{2}$$

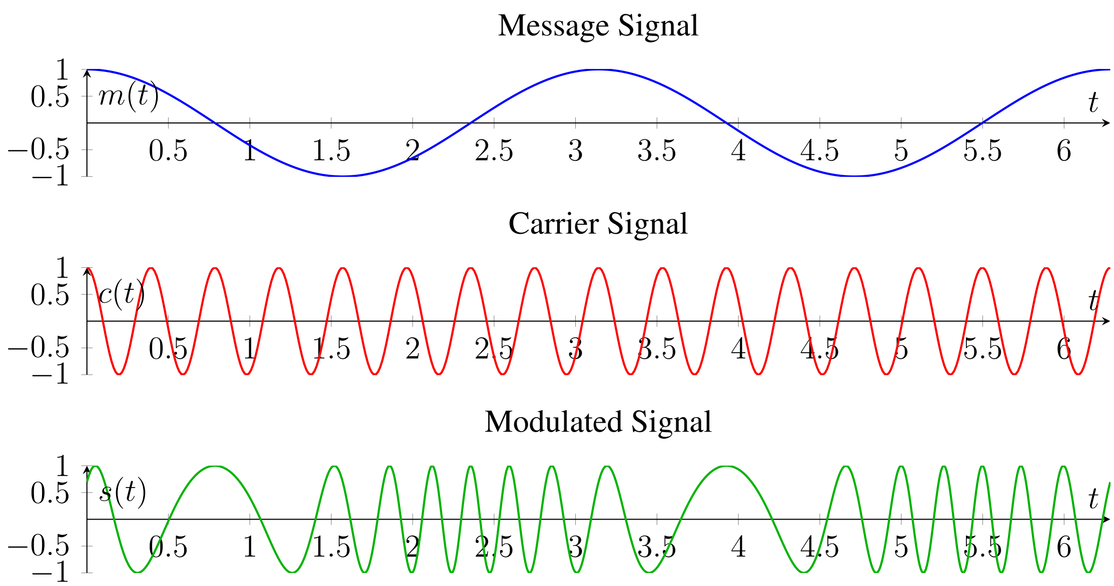

Figure 1: Frequency Modulation Scheme

1.1.1 Modulation

To generate a PM Singal, we use an oscillator to generate the carrier signal and then modulate the phase of the carrier with the message signal.

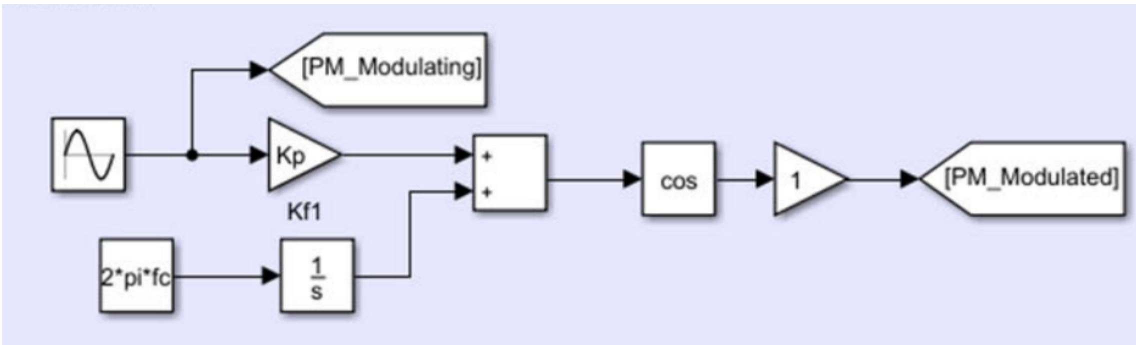

Figure 2: Phase Modulation
[?]

1.1.2 Demodulation - Phase Locked Loop

For demodulation, a common method is the phase-locked loop (PLL) a feedback system that synchronizes the phase of the output signal with the phase of the input signal. The phase detector compares the phase of the input signal with the phase of the output signal and generates an error signal that is used to adjust the phase of the output signal. The output of the phase detector is filtered using a low-pass filter to remove high-frequency components, resulting in a demodulated signal, but the outputs signal is proportional to the derivative of the message singal.

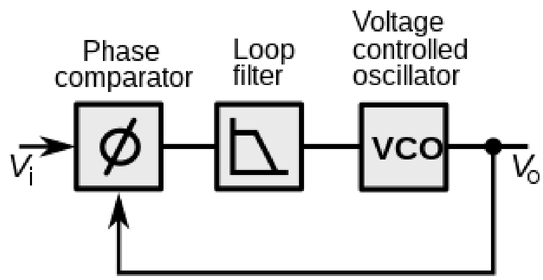

Figure 3: Phase Locked Loop
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2 Procedure and Data Analysis

2.1 Modulation

In this part, we modulated a message signal having 2V VSS and 1kHz frequency over a carrier with 20kHz frequency.

2.1.1 Time Domain

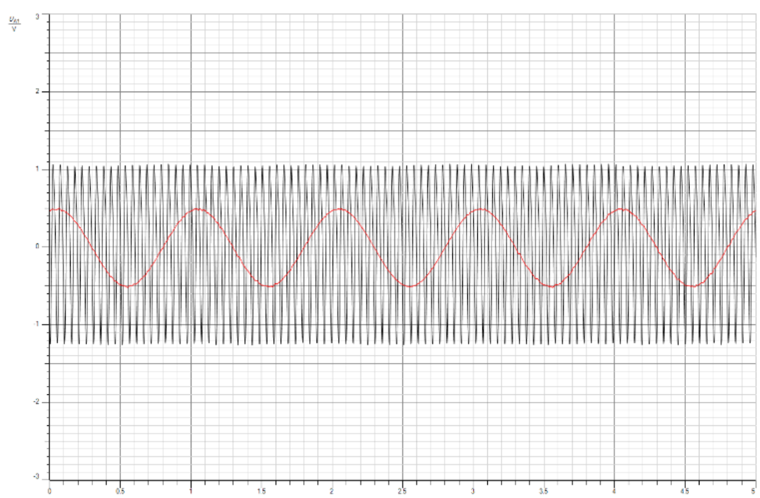

Figure 4: Time Domain

2.1.2 Frequency Domain

In order to set the carrier frequency to 20kHz, we set the message signal to 0, so the modulated signal is just the carrier signal.

$$\begin{aligned} s(t) &= A_c \cos(\omega_c t + k_p \times m(t)) \\ s(t) &= A_c \cos(\omega_c t + k_p \times 0) \\ s(t) &= A_c \cos(\omega_c t) \end{aligned} \tag{3}$$

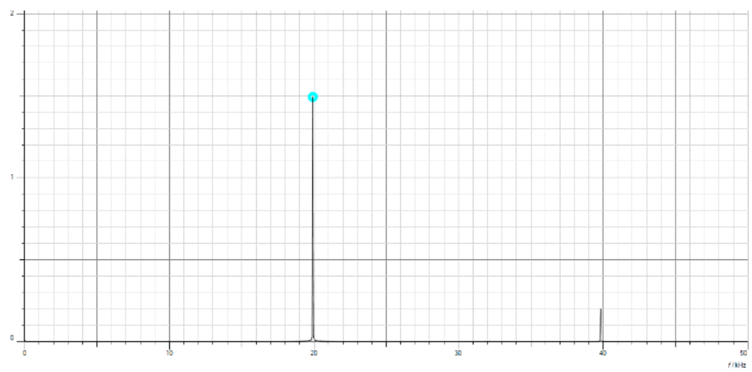

Figure 5: Frequency Domain

From the graph above $f_C = 19.91kHz$, furthermore,we noticed that the modulated signal isn't affected by the amplitude of the message signal, but the frequency of the message signal affects the frequency of the modulated signal.

2.1.3 Setting Carrier Frequency

2.1.4 Characteristics of the FM Modulator

The main Characteristic of the FM modulator is the modulation sensitivity K_p, using the instantaneous frequency equation:

$$f_i = f_c + k_p m(t) \tag{4}$$

using a constant amplitude would result

$$f_i = f_c + k_p \times A_m \tag{5}$$

with f_c being the carrier frequency, k_p being the modulation sensetivity, and A_m being the amplitude of the message signal.

2.2 PM Modulator Characteristic

Voltage	-1	-0.8	-0.6	-0.4	-0.2	0	0.2	0.4	0.6	0.8	1
Δt	-0.006	-0.005	-0.005	-0.005	-0.004	-0.003	0	0.001	0.003	0.006	0.006
$\Delta\phi$	-119.4	-99.5	-99.5	-99.5	-79.6	-59.7	0	19.9	59.7	119.4	119.4

Table 1: PM Modulator Coefficient - k_p

Plotting $\Delta\phi$ over $Voltage$ gives us the modulator coefficient K_p as shown below:

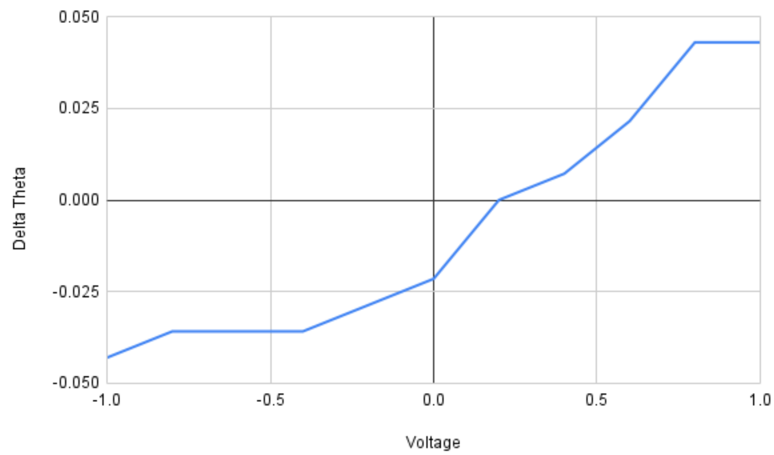

Figure 6: Modulator Coefficient - k_p

Using excel we calculated the slope of the line to be $k_p = 19.61$.

2.3 PM Signal Specturm

In this part, we studied the effect of Freqeuncy on the modulated singal, by using a constant 2V VSS message with 2 different frequencies 3000Hz and 200Hz and the results were as follows:

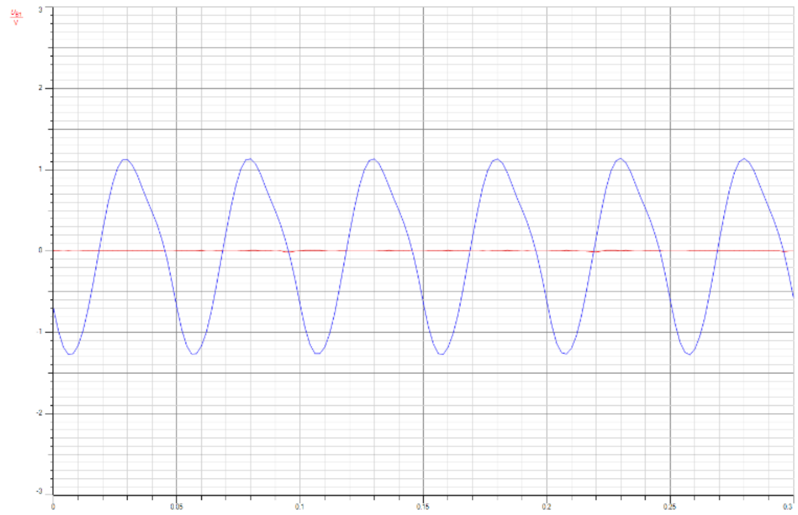

Figure 7: $f_m = 3000Hz$ in time domain

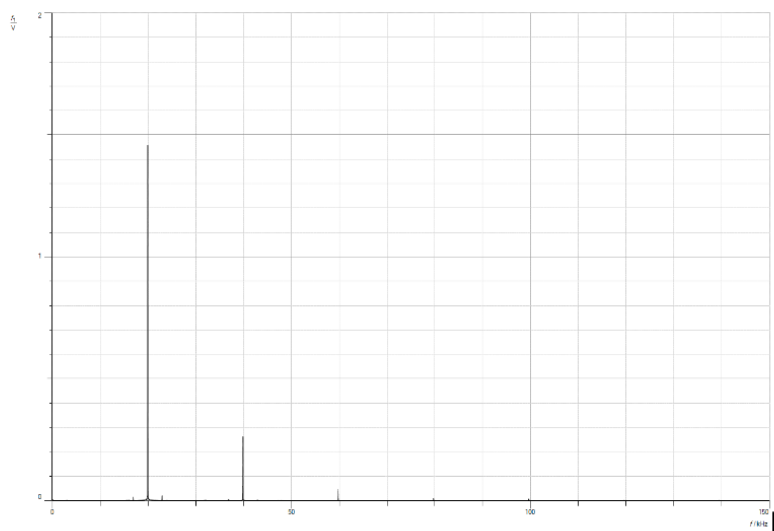

Figure 8: $f_m = 3000Hz$ in frequency domain

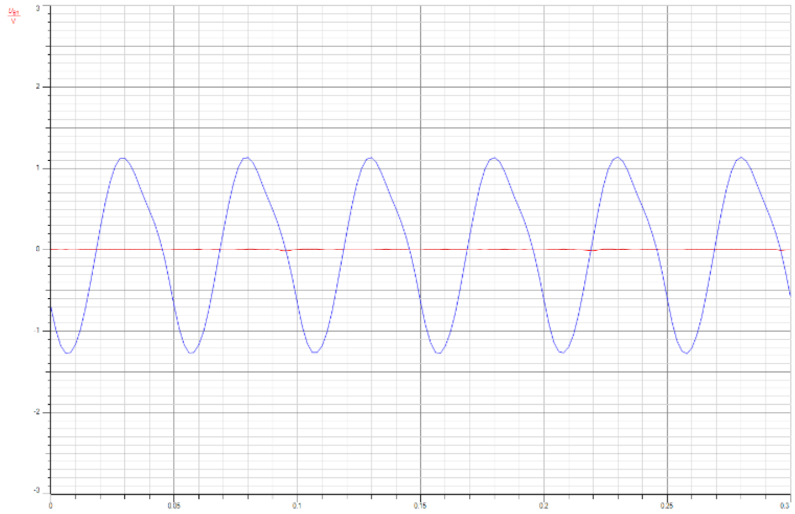

Figure 9: $f_m = 200Hz$ in time domain

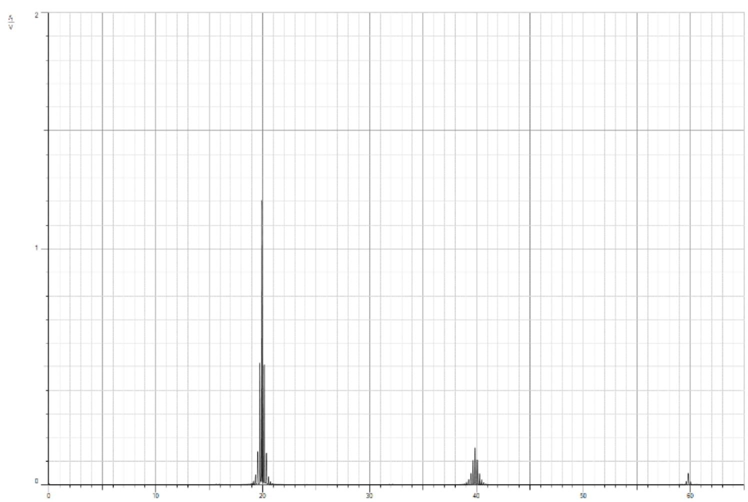

Figure 10: $f_m = 200Hz$ in frequency domain

We noticed that the spectrum keeps repeating itself, and the period of repetitions is equal to the frequency of the message signal. And we can't tell the difference between a FM and PM signal from the spectrum.

2.4 Demodulation

2.4.1 Time Domain Demodulatio

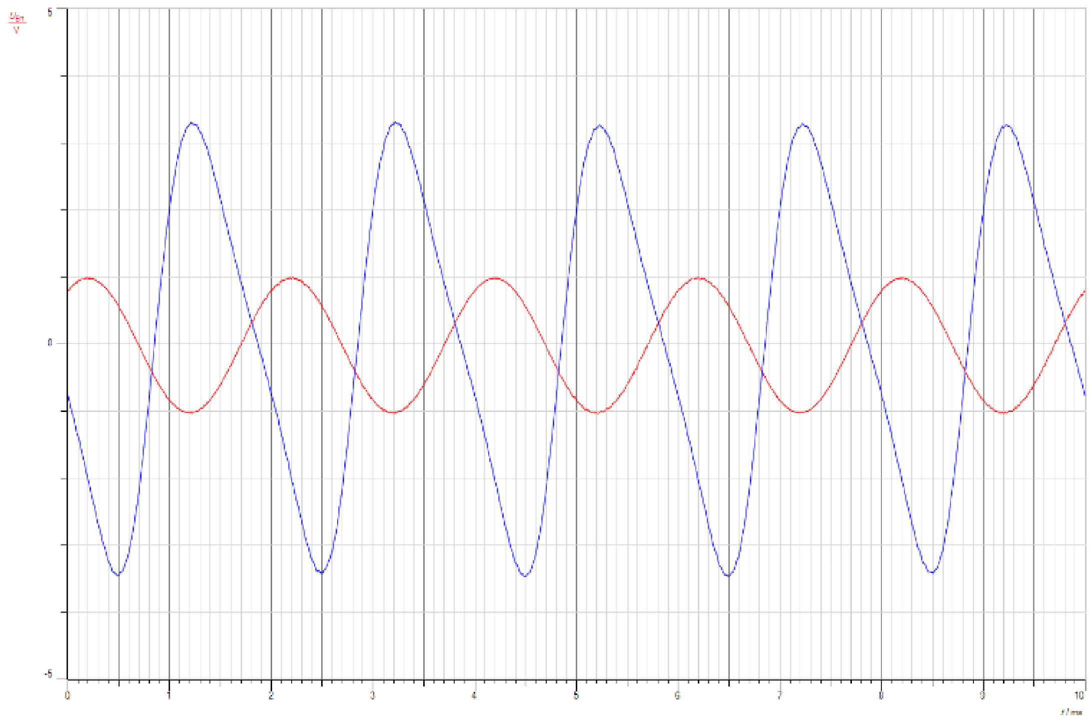

Figure 11: Demodulated Signal in time domain

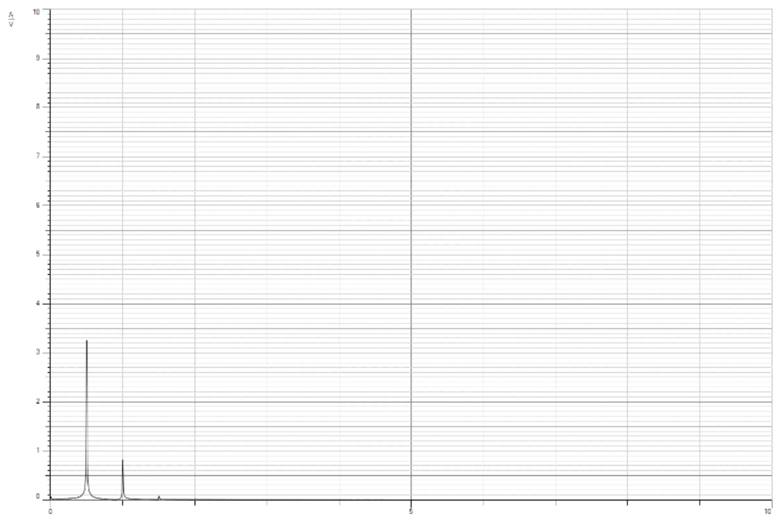

Figure 12: Demodulated Signal in frequency domain

We have recoverd the message signal, hence PLL is working with PM, and the demodulated signal is the same as the message signal but with a different amplitude.

2.4.2 Studying Loop filters

Frequency	500	1000	1500	2000	3000	4000
τ_1	12.41	4.77	2.44	1.46	0.63	0.36
τ_2	3.25	2.81	2.11	1.57	0.77	0.43

Table 2: τ_1, τ_2 vs frequency

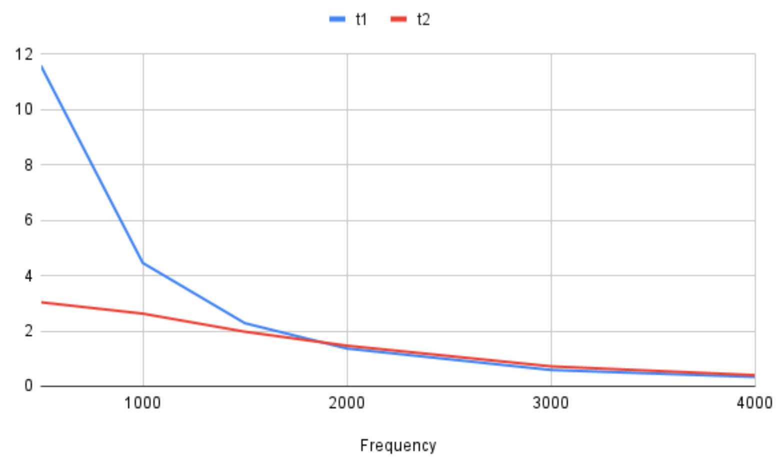

Figure 13: τ_1, τ_2 vs frequency

We notice that τ_1 and τ_2 are inversely proportional to the frequency, and that τ_1 is always greater than τ_2.

3 Conclusion

In conclusion, we have studied the PM modulators and demodulators, the effect of the message signal on the modulated signal, the effect of the frequency on the modulated signal, and Nthe effect of the loop filter on the PLL.

References

References

[1] Enee4113 prelab manual.

[2] Wikipedia. Phase-locked loop. https://en.wikipedia.org/wiki/Phase-locked$_{l}oop/$