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Faculty of Engineering & Technology
Electrical & Computer Engineering Department

Communications Lab - ENEE4103

Pre-Lab #1

Experiment NO. 1: AM and DSB-SC Modulation and Demodulation

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partners names and IDs?

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Section: 4

Date: 11-04-2023

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Abstract

The aim of the experiment is to understand and simulate the modulation and demodulation of normal AM using Matlab. The modulatingsignal, modulated signal, carrier, and demodulated signal are to be measured and sketched in both time and frequency domains using CASSY software, in addition to performing some calculations to find the modulation index. Also, the experiment aims to observe the effect of changing different parameters on the measured values.

In AM radio transmission, the amplitude of the carrier wave changes proportionally to the voltage or power level of the information stream. The AM carrier is just sent by itself when there is no modulation. The amplitude of the carrier wave rises and falls in response to the application of a modulating information signal (a sine wave). AM transmission uses a steady carrier frequency.[1]

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one paragraph only

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1 Theory

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1.1 Analog Modulation

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An analog signal is a continuous wave where the time differing variable of the wave is represented in relation of other time differing quality which is analogous to other time changing signals. And analog modulation is the procedure of transmitting low-frequency signals such as TV signals or audio signals with that of high-frequency carrier signals like that of radio frequency signals. In this type of modulation, a band pass channel is required where it corresponds to the specified range of frequencies. These frequencies are transmitted over a band pass filter which allows certain frequencies to pass preventing signals at undesirable frequencies. [1].

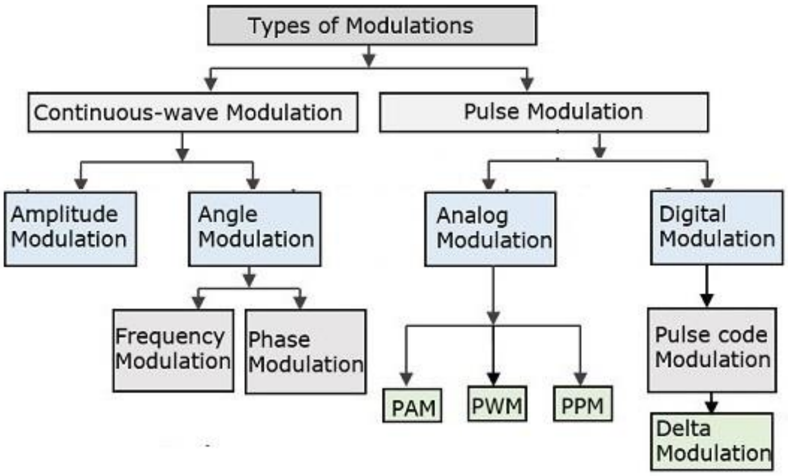

Figure 1.1: Types of Modulation [2]

Three components of analog modulation exist, each with a different set of characteristics.:

- Amplitude Modulation (AM)
- Frequency Modulation (FM)
- Phase Modulation

1.2 Amplitude Modulation (AM)

In amplitude modulation, the modulating signal's amplitude determines the carrier amplitude, which changes while the frequency remains constant. Also, there are other types of amplitude modulation, such as Normal AM and DSB-SC.

1.3 Normal AM

The mathematical expression describes the normal amplitude modulation.:

$$s(t) = A_c[1 + k_a m(t)]cos(2\pi f_c t)$$

Where $A_c cos(2\pi f_c t)$ is the carrier signal, *m(t)* is the message signal, and k_a is the sensitivity of AM modulator.

The message data will be contained in the envelope of the resulting modulated signal, which has the same shape as the modulating signal. The envelope is described as the imaginary line joining the tips of the modulated signal. [4]. It can be described using the following formula:

$$Envelope = A(t) = A_C|1 + k_a m(t)|$$

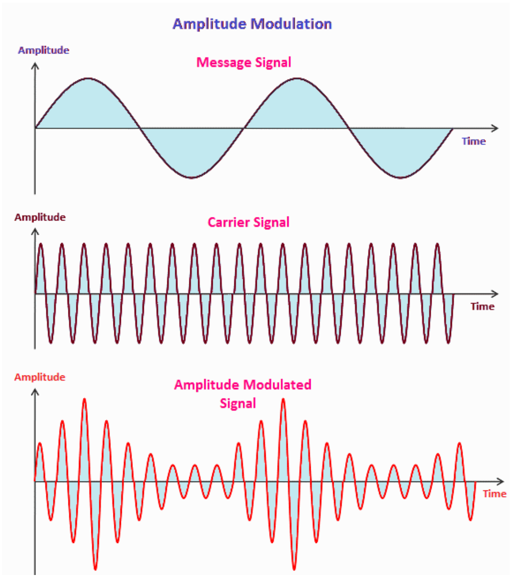

Figure 1.2: Normal AM Modulation [3]

The frequency domain representation of the previous expression is given by:

$$S(f) = \frac{Ac}{2}[\delta(f - fc) + \delta(f + fc] + \frac{AcKa}{2}[M(f - fc) + M(f + fc)]$$

In addition to carrier impulses, the resulting modulated signal also includes a shifted version of the modulating signal that is centered at the carrier frequency, as seen in Figure. 1.3.

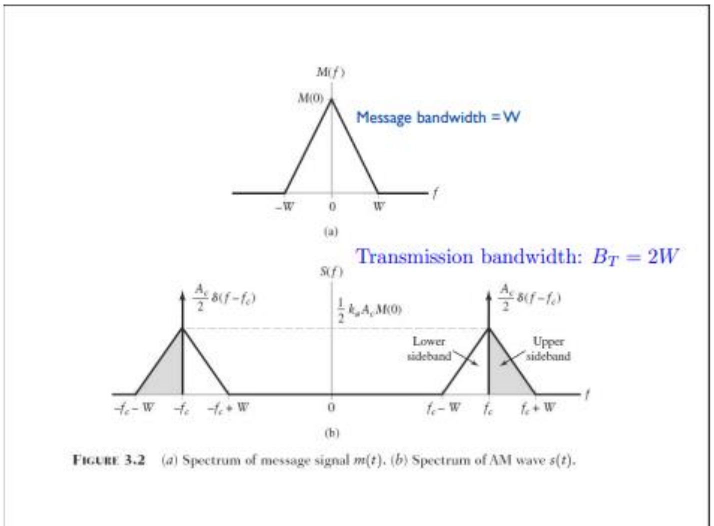

Figure 1.3: Normal AM Spectrum [4]

The bandwidth of the modulated signal equals $f_C + B - (f_C - B) = 2B$, which is twice the message bandwidth.

The modulation process can be described as follows:

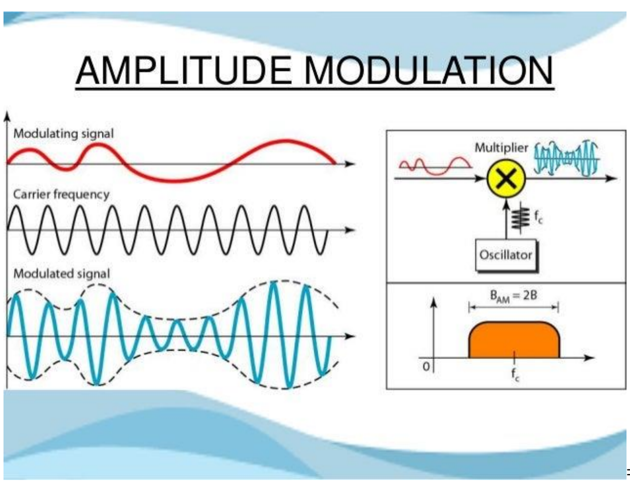

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Figure 1.4: Normal AM Modulation [5]

Demodulation is the process of recovering the message signal at the receiver end. This can be accomplished with a coherent detector or envelope detection for standard AM..

The envelope detector makes an effort to track down the modulated signal's leading edges in order to recover the message signal. A diode and a capacitor can be used to build a practical detector, and the envelope that is detected depends on the time constant r = RC. These detectors, however, frequently cause substantial distortion.

Contrarily, the coherent detector displays less distortion when the frequency and phase at the demodulator and modulator are the same.

1.4 Modulation Index μ

The amount of amplitude change around an unmodulated carrier is referred to as the modulation index of an amplitude modulated signal. In other words, the modulated carrier envelope's variation from the static level is described by the amplitude modulation index.

The modulation index can be expressed mathematically as follows :

$$\boldsymbol{\mu} = \frac{\Delta Ac}{Ac} = \frac{2\left|(Amax-Amin)\right|}{2\left|(Amax+Amin)\right|} = \frac{\left|D-d\right|}{D+d\left|\right.}$$

Where:

D: Peak-to-peak value of the maximum of the AM signal

d: Peak-to-peak value of the minimum of the AM signal

According to the value of the modulation index, the modulation can be divided into three types based on its relationship to the modulated signal envelope.:

- Under-Modulation: The case where the modulation index is less than one, causing no envelope distortion.

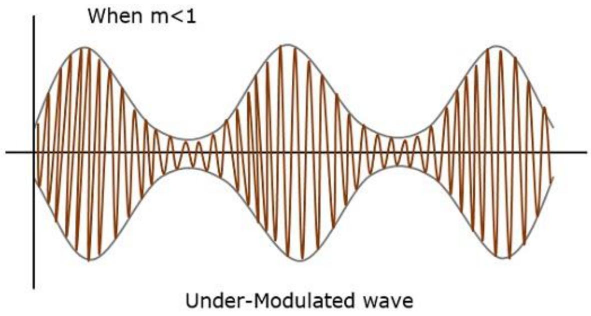


Figure 1.5: Under-Modulation [6]

- Full-Modulation: In this case, the modulation index is 1. The level of the envelope increases to twice the unmodulated level in this case without experiencing envelope distortion before why all of this space

dropping to zero.

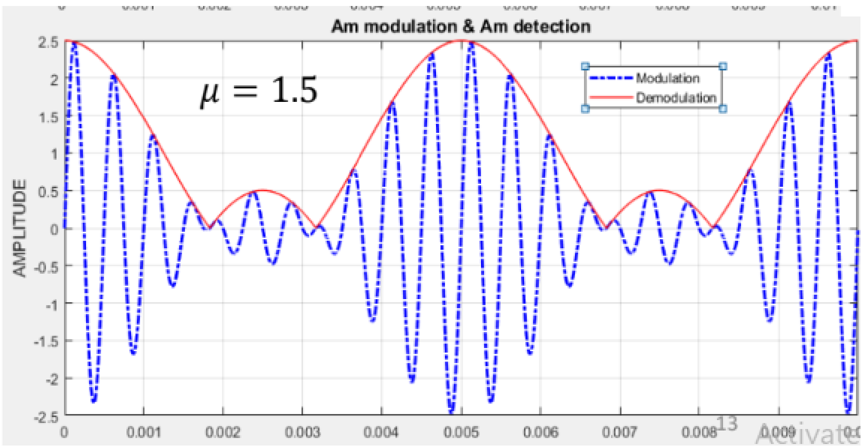


Figure 1.6: Full-Modulation [7]

- Over-Modulation: The modulation index in this case is greater than one, and causes an envelope distortion.

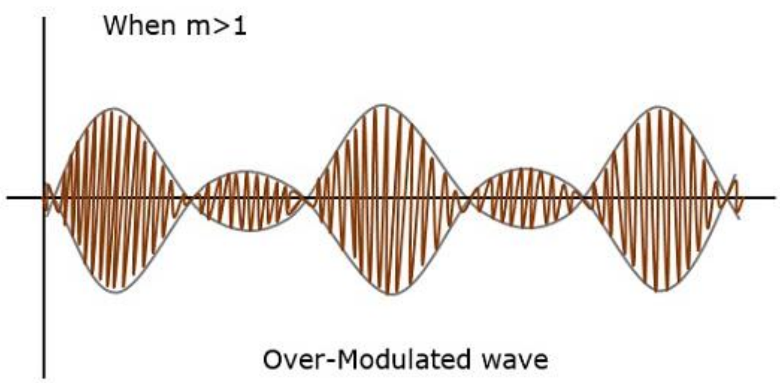


Figure 1.7: Over-Modulation [8]

1.5 Coherent Detection

This method multiplies the modulated signal by employing a locally generated carrier that has the same frequency and phase as the carrier being used for modulation. Once the signal has been given to it, the message signal is then retrieved using a low-pass filter.

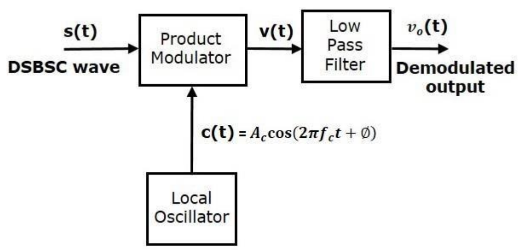


Figure 1.10: Coherent Detection [7]

However, if the locally generated carrier is non-coherent (contains a frequency or phase difference), this will affect the demodulated signal as follows:

- Phase non-coherence: the demodulated signal will look like $y(t) = \frac{A_c A_c'}{2} m(t)\cos\emptyset$. No distortion here, but possibly an attenuation since the cosine range is between 0 and 1. However, if the phase equals 90° the message will disappear, this is called the quadrature null effect.

- Frequency non-coherence: the demodulated signal will look like $y(t) = \frac{A_c A_c^F}{2} m(t)\cos(2\pi\Delta f t)$. The message signal is distorted due to the presence of an additional cosine term.

Phase-Locked Loop (PLL) technology can be used to create the local carrier. In essence, a phase-locked loop compares the phase of an adjustable feedback signal (RF_{IN}) F0 to the phase of a reference signal (F_{REF}). For comparison, a negative feedback control loop that operates in the frequency domain is used. We say that the PLL is locked when the comparison is steady-state and the output frequency and phase match the incoming frequency and phase of the error detector. [8]

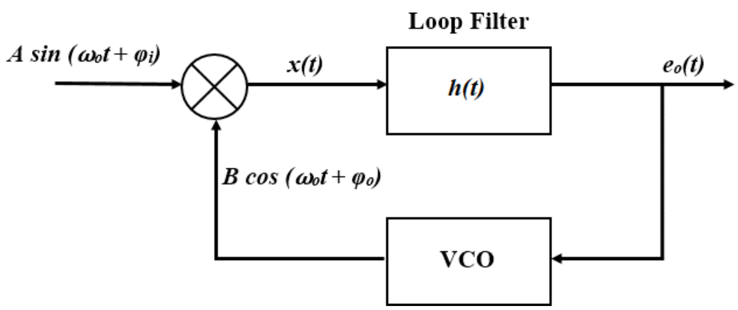


Figure 1.11: PLL Block Diagram [9]

1.6 Power Efficiency η

The ratio between the power in the sidebands and the total power in the transmitted signal serves as a measure of the modulation's power efficiency.

$$\eta = \frac{power\ in\ the\ sidebands}{total\ power}$$

For the normal AM with a sinusoidal signal, the power efficiency is:

$$\eta = \frac{power\ in\ the\ sidebands}{power\ in\ the\ sidebands + carrier\ power} = \frac{\mu^2}{2+\mu^2}$$

Where µ is the modulation index.

The maximum power efficiency is obtained when µ = 1, resulting in $\eta = \frac{1}{3} \approx 33.33\%$

dont just copy paste the theory. write it with your own language

2.1/4.5

2 Procedure, Results and Discussion

2.1 Part One: Normal AM Modulation

The circuit in figure 2.1.1 was connected with the CARRIER ON setting, to simulate the normal AM. The function generator was set to: sine, $V_{SS} = 4$ V and $f_M = 2$ kHz.

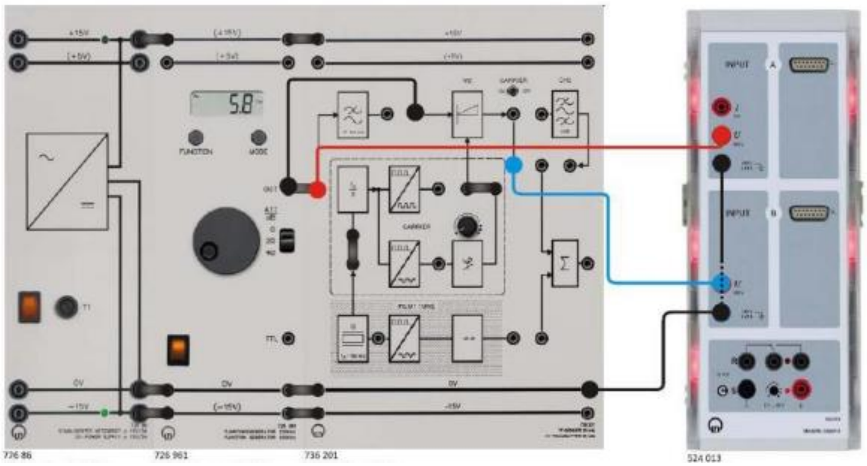


Figure 2.1: Normal AM Modulation Circuit

The modulated signal $S_{AM}(t)$ along with the message signal M(t) are shown in figure 2.1.2

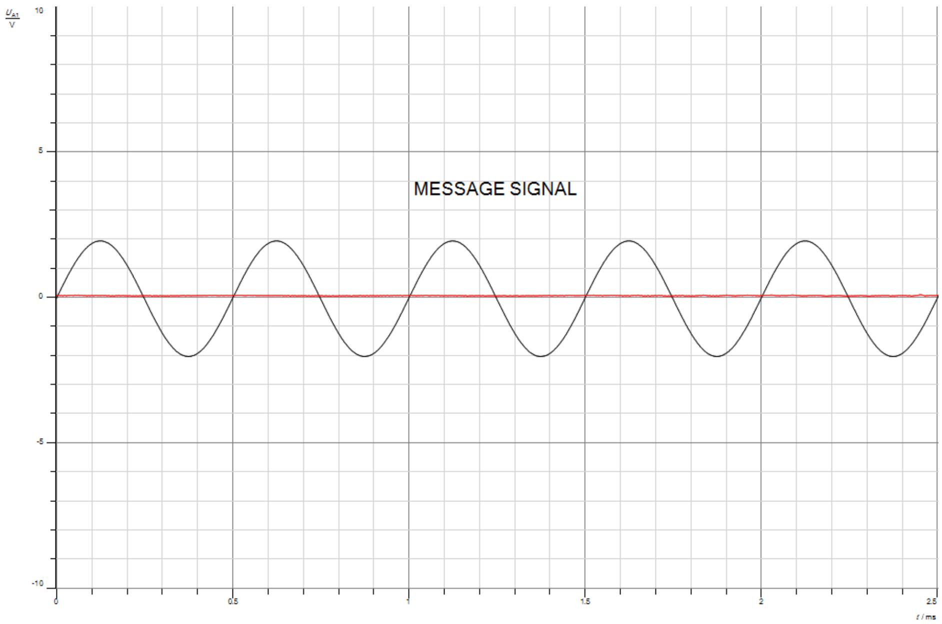


Figure 2.2: Normal AM modulated & modulating signals with A_M = 4 V and f_M=2 kHz

- : message signal

2.1.1 Carrier signal:

discuss what you've done to show the carrier signal

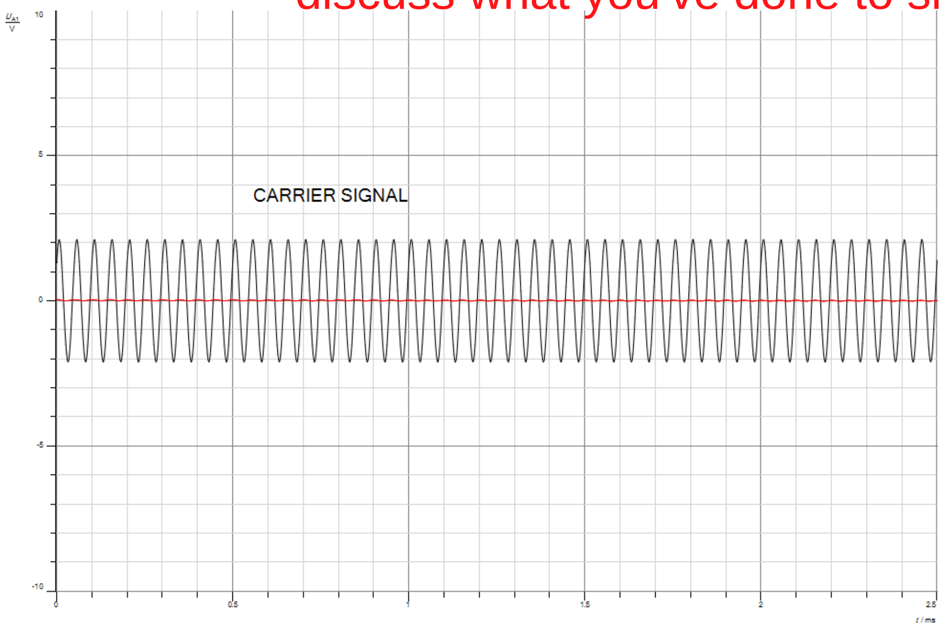
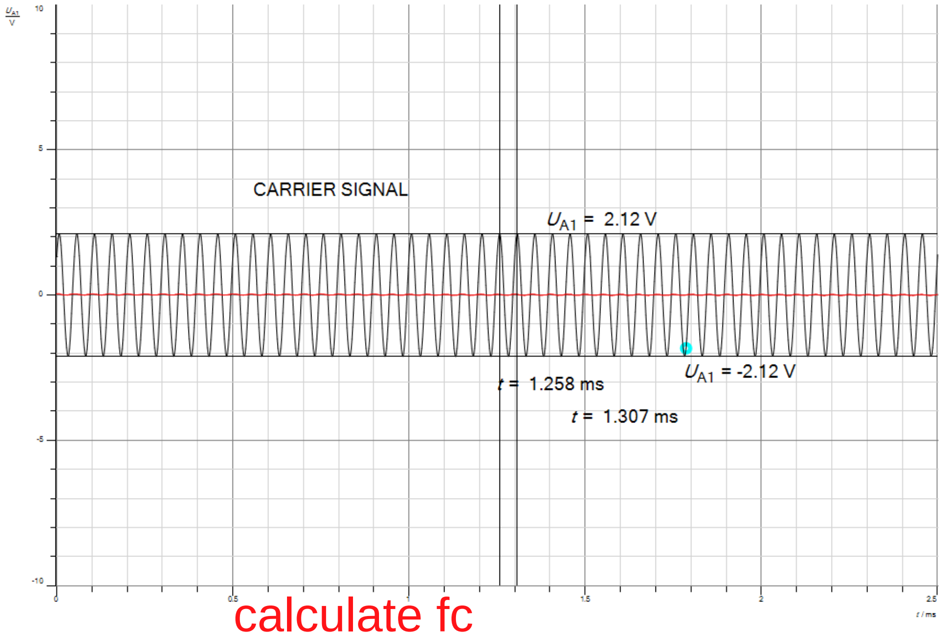


Figure 2.3: Normal AM Modulated & Modulating Signals with $A_M = 4$ V and $f_M = 2$ kHz

Modulated signal:



calculate fc

Figure 2.4: Normal AM Modulated & Modulating Signals with $A_M = 4$ V and $f_M = 2$Hz

- modulated signal

use passive voice, dont use we or I..

We can see that the modulated signal's envelope matches the message signal in shape. The modulation index is less than one since there isn't any distortion in the shape of the envelope but there isn't full modulation, which results in less than 1/3 power efficiency.

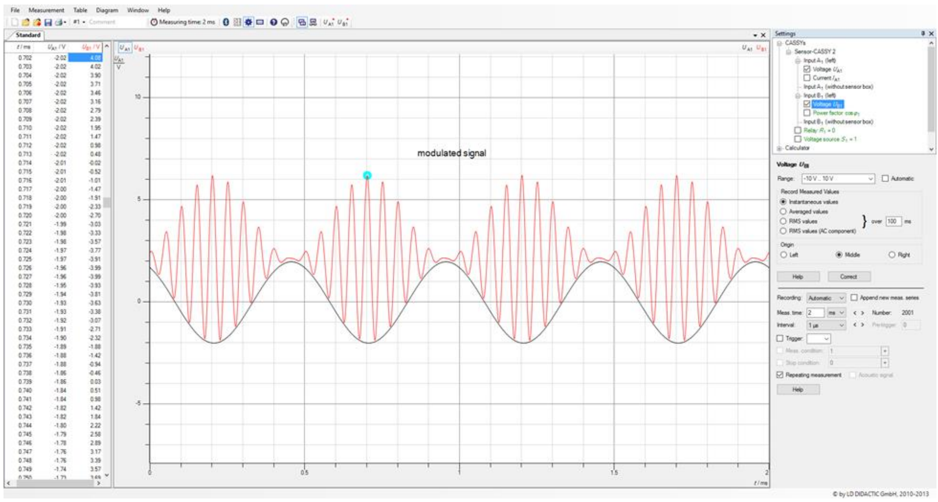
We can notice that the result of modulation is :

$$s(t) = \left(1 + Km(t)\right)c(t) = c(t) + Km(t)c(t)$$

That the output value is defined by : (dc+ message)* carrier , actually (carrier +message * carrier).

Modulation index(μ):

Initially, AM = 4 V was used to calculate the modulation index. The modulated signal's time domain representation was utilized to determine Amax and Amin, and the values was then entered into the formula to determine.



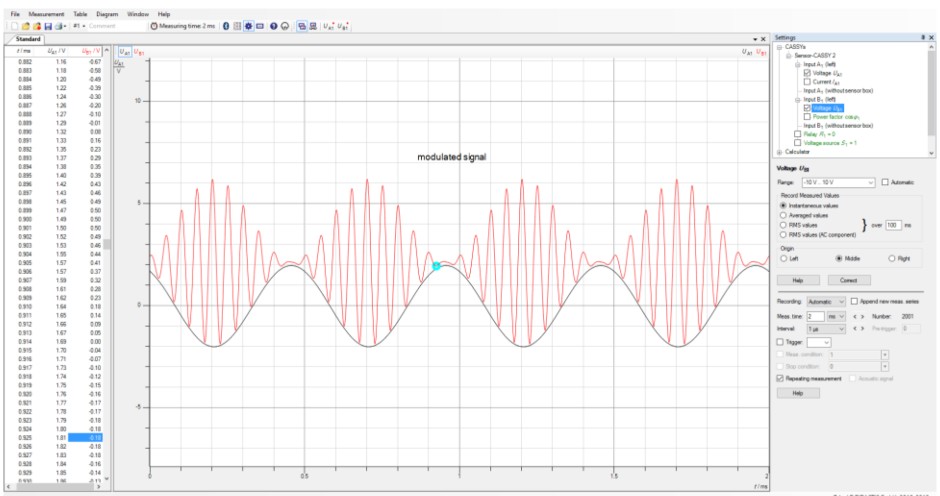


Figure 2.5: Normal AM Modulated & Modulating Signals with $A_M = 4$ V and $f_M = 2$ kHz

Amax=4.08

Amin -0.18

Modulation sensitivity (k):

μ=ka*Am

$1 = ka * 2 = ka = 0.5$

Changing Frequency :

At 1 kHz

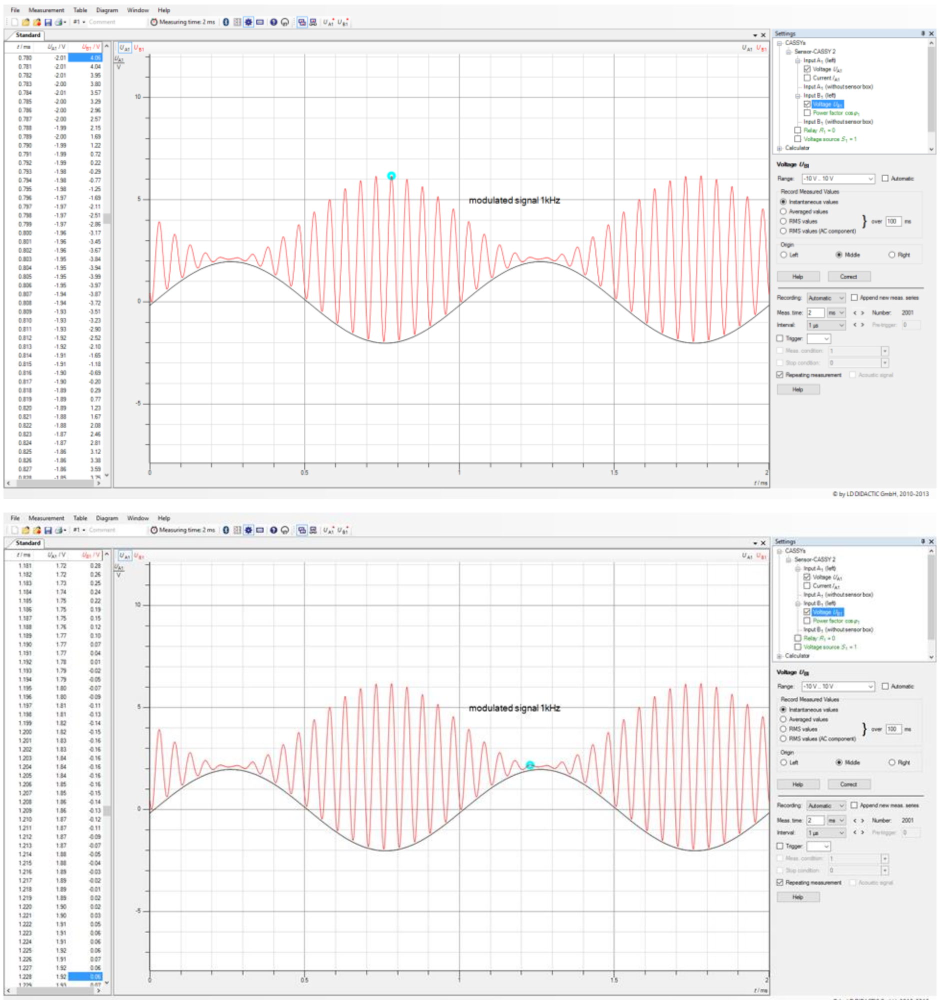


Figure 2.6: Normal AM Modulated & Modulating Signals with A_M = 4 V and f_M = 1kHz

Amax = 4.06 , Amin = -0.06

$$\mu = \left| \frac{(4.06 - -0.06)}{(4.06 \pm 0.06)} \right| = 1.03$$

At 3 KHZ

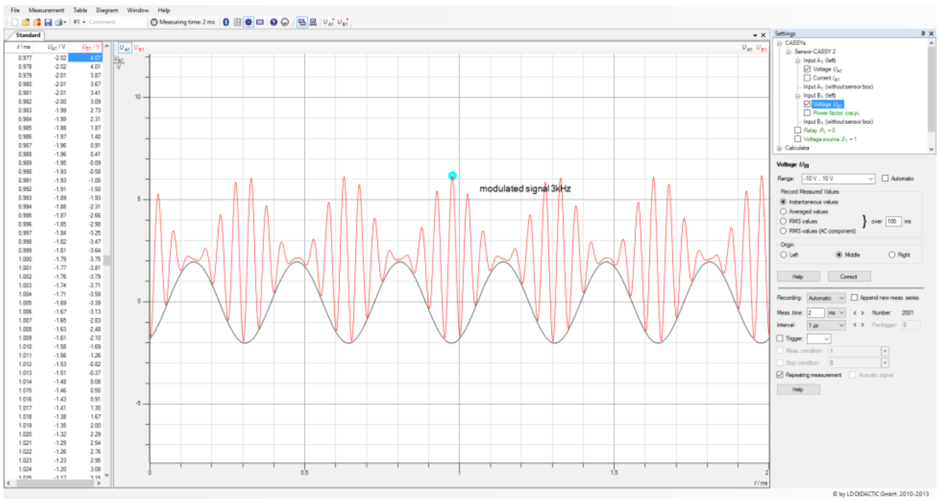


Figure 2.7: Normal AM Modulated & Modulating Signals with $A_M = 4$ V and $f_M = 3$kHz

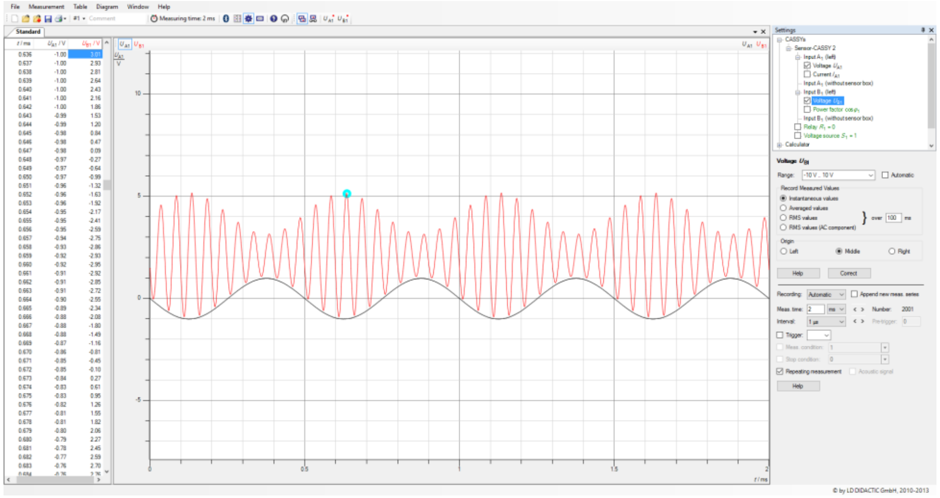
Amax =4.07 , Amin = 0 (the figure when Amin =0 We missed taking a screenshot of the Cassy Lab)

$$\mu = \left| \frac{(4.06 - 0)}{(4.06 + 0)} \right| = 1$$

The bandwidth needed to transmit the modulated signal increases as the message signal's frequency rises (BW = 2fM). Additionally, the number of tips that create the envelope reduces for each period as the message frequency is increased to 8 kHz (50% of the carrier frequency), making it impossible to detect the message signal using the envelope detector. On the other hand, decreasing the message frequency results in decreasing the bandwidth.

discuss the effect of changing fm on the modulation index write the steps of the procedure done in each part

Changing The Amplitude:



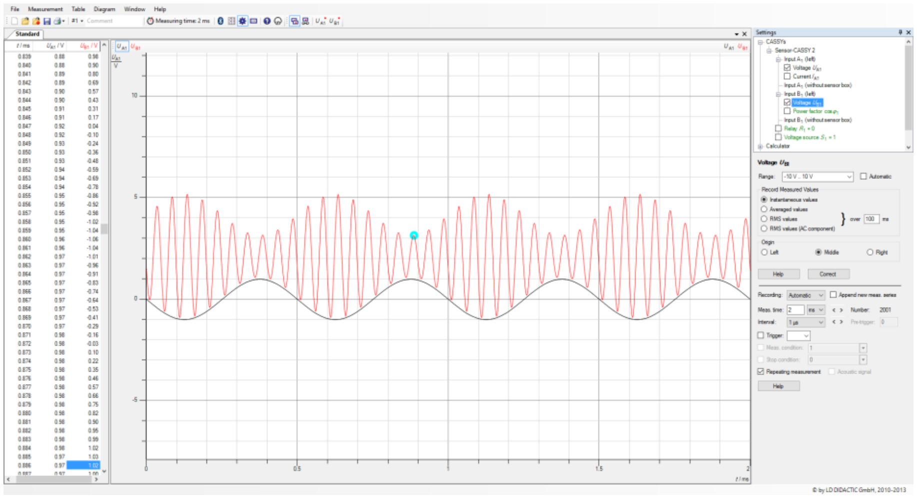
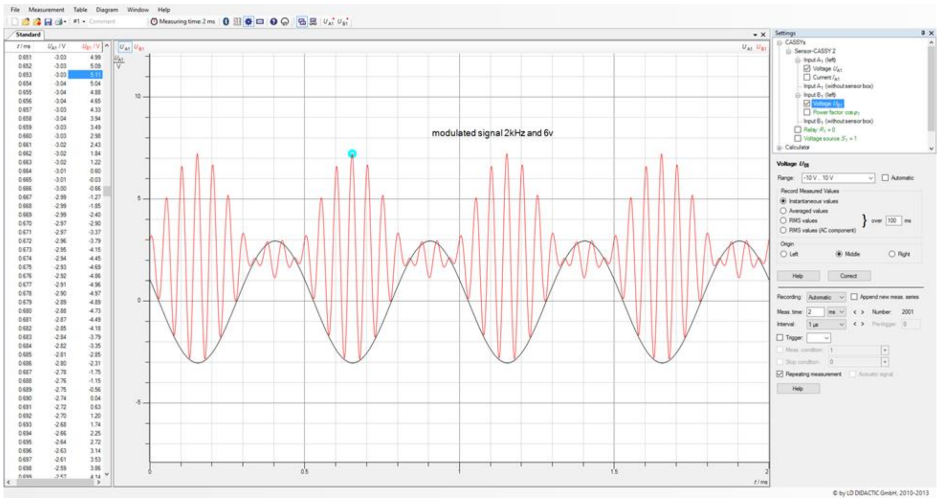


Figure 2.8: Normal AM Modulated & Modulating Signals with Vss = 2 V and f_M = 2kHz

Amax = 3.01 , Amin = 1.02

$$\mu = \mid \frac{(3.01 - 1.02)}{(3.01 + 1.02)} \mid = 0.493$$



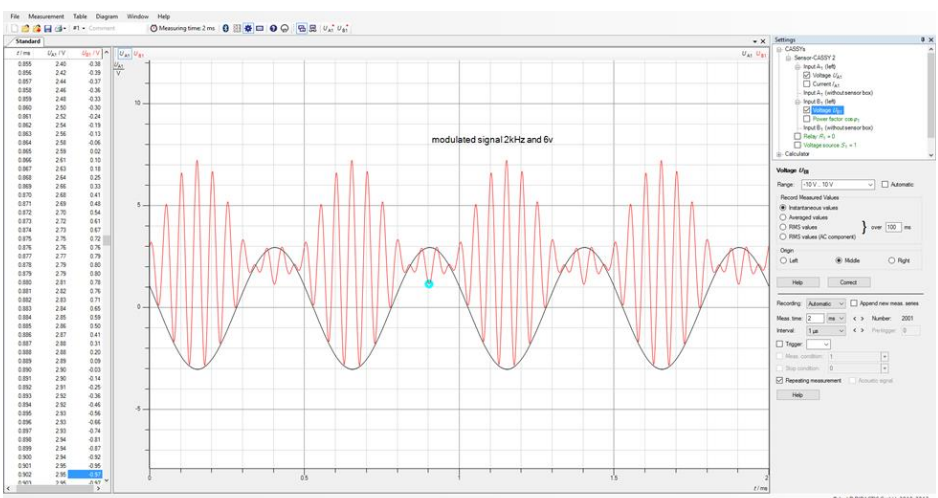


Figure 2.9: Normal AM Modulated & Modulating Signals with Vss = 6 V and f_M = 2kHz

Amax = 5.11 , Amin = -0.97

$$\mu = \mid \frac{(5.11 - -0.97)}{(5.11 \pm 0.97)} \mid = 1.468$$

By increasing AM, the modulation index grows, which raises power efficiency.
The envelope of the modulated signal, however, is distorted and cannot be recovered using the envelope detection demodulation if the modulation index rises above one, as is the case when $|A(t)| \neq A(t)$.

2.1.2 LPF shift Effect :

A low pass filter is a circuit whose amplitude (magnitude) function drops as grows, meaning that it rejects high frequencies (which have relaively tiny output amplitudes) while passing low frequencies.

discuss what the LPF did with the signals (phase shift)

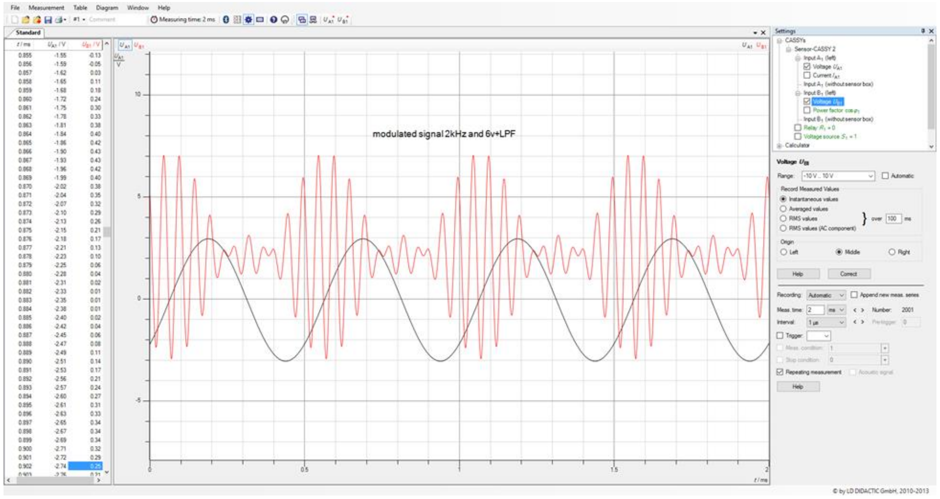


Figure 2.10: Normal AM Modulated & Modulating Signals with Vss = 6 V and fM = 2kHz +LPF

2.1.3 Frequency Modulation:

1-Message Signals:

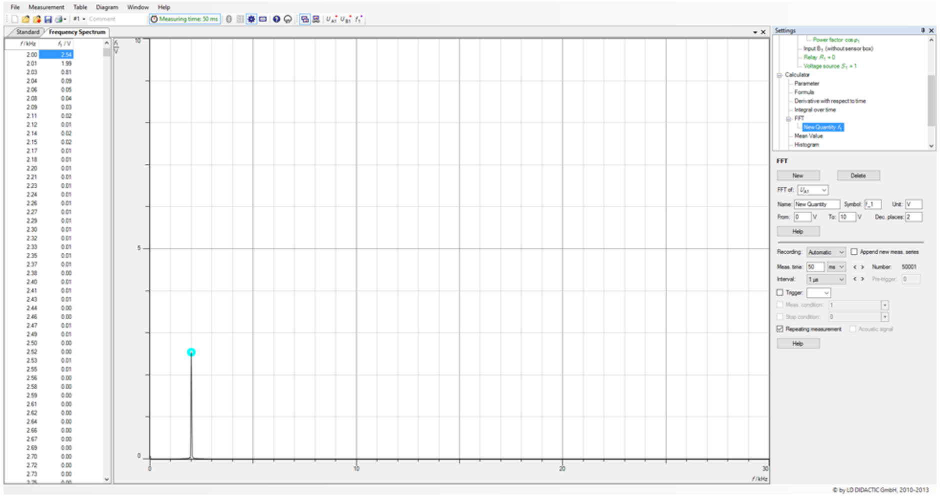


Figure 2.11: Message signal in Frequency Domain

2-Carrier Signal :

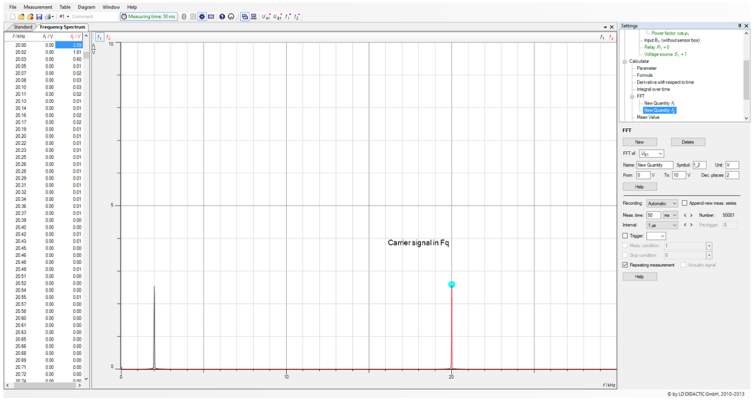


Figure 2.12: Carrier signal in Frequency Domain

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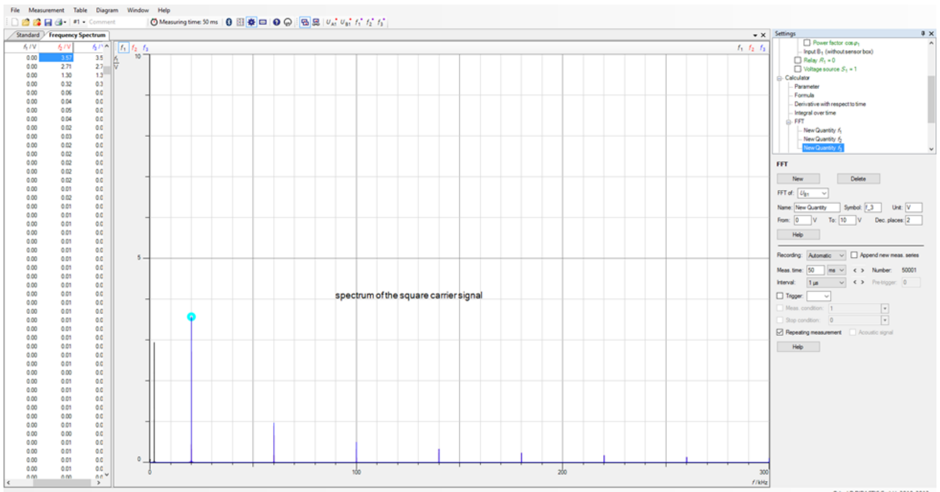

Figure 2.13: Square Carrier signal in Frequency Domain

3- Modulated signal:

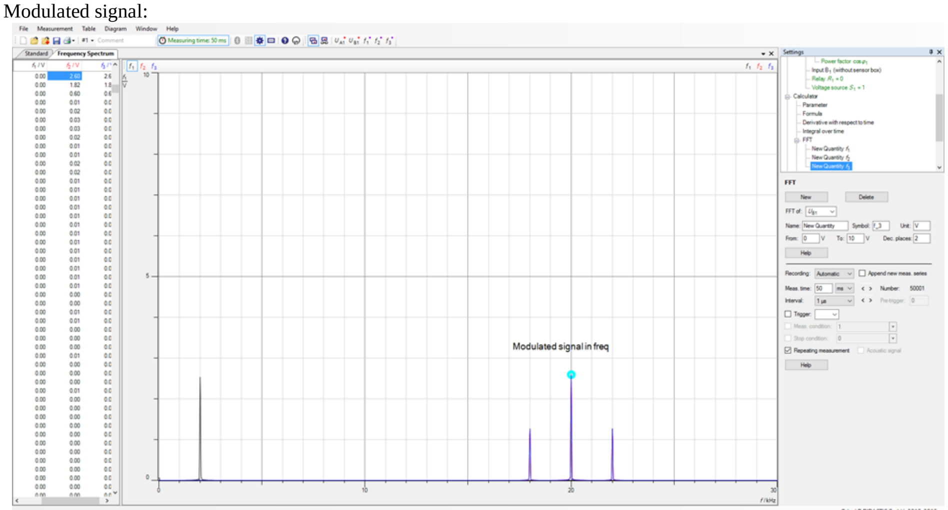

Figure 2.14: Normal AM Modulated in Frequency Domain

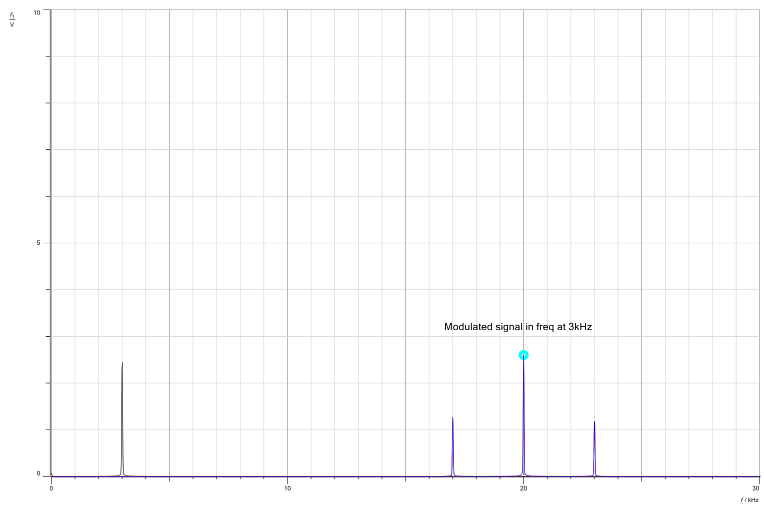

Figure 2.15: Normal AM Modulated in Frequency Domain with Vss=4V and fm=3kHz

2.2 Part Two: Normal Amplitude Demodulation

The same connections as in part one were connected, but with the toggle switch set to CARRIER OFF. Hence, the carrier was suppressed and the DSB-SC was simulated. The function generator was set to: sine, $V_{SS} = 4$ V and $f_M = 2$ kHz.

We can notice from the figures 2.2.1 & 2.2.3, that the envelope of the modulated carrier S(t) does not represent the message signal. Hence, envelope detection cannot be used to demodulate this type of amplitude modulation.

2.2.1 Coherent Demodulation

When connecting the message directly to the mixer, without passing it through a low-pass filter, the message signal M(t) will be in phase with the modulated signal S(t), as shown in Figure 2.2.16

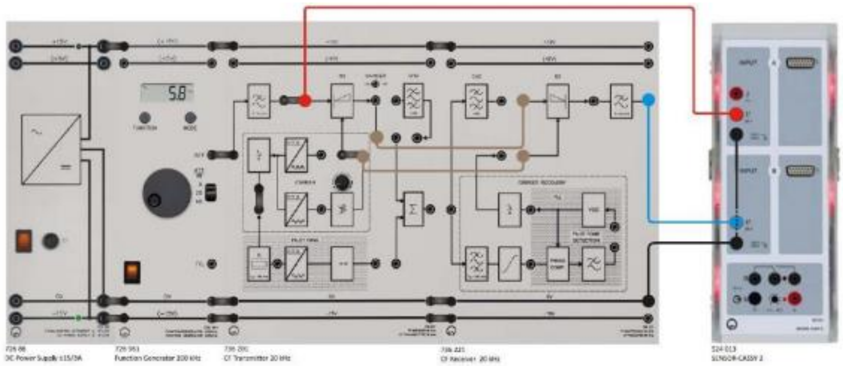

Figure 2.16: Coherent Demodulation

Between the carrier at the modulator and the carrier at the demodulator, there is no phase shift during coherent modulation. The demodulated signal is a scaled-down counterpart of the modulating signal, as can be seen in the figure. The low-pass filter at the conclusion of the demodulation process is what causes the phase shift between the modulating signal and the demodulated signal.

justify your paragraphs

2.2.2 Non-Coherent Demodulation

When passing the message through a low pass filter, a phase shift occurs to the message. This is due to the characteristics of the filter, represented in constant amplitude scaling and a phase shift. However, this phase shift does not cause a distortion. The phase shift can be seen in figure 2.2.3 bellow.

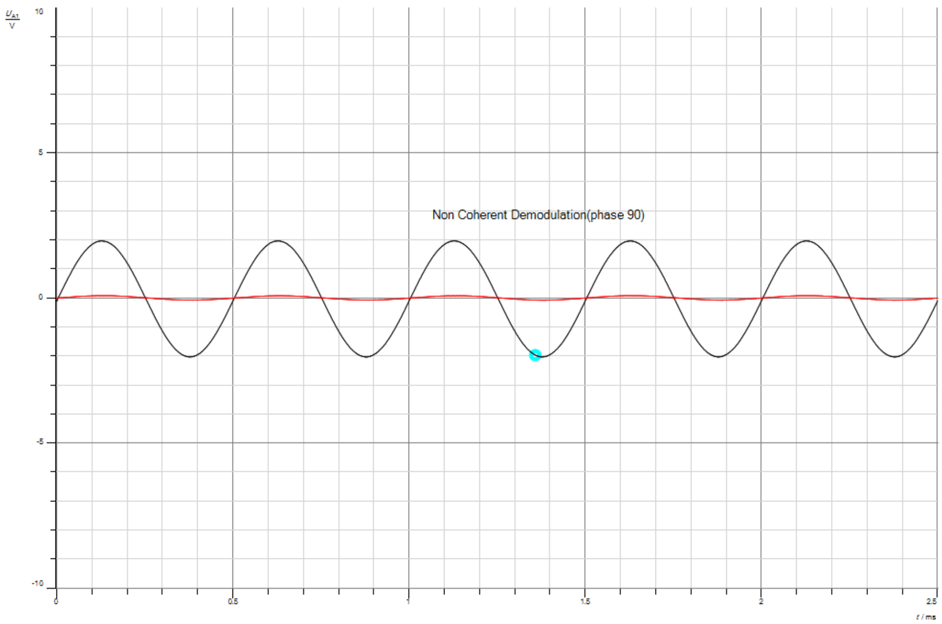

Figure 2.17: Non-Coherent Demodulation

2.2.3 Phase Locked Loop (PLL) Coherent Demodulation

In this section, demodulation is done using the recovered auxiliary carrier from the PLL carrier Recovery .

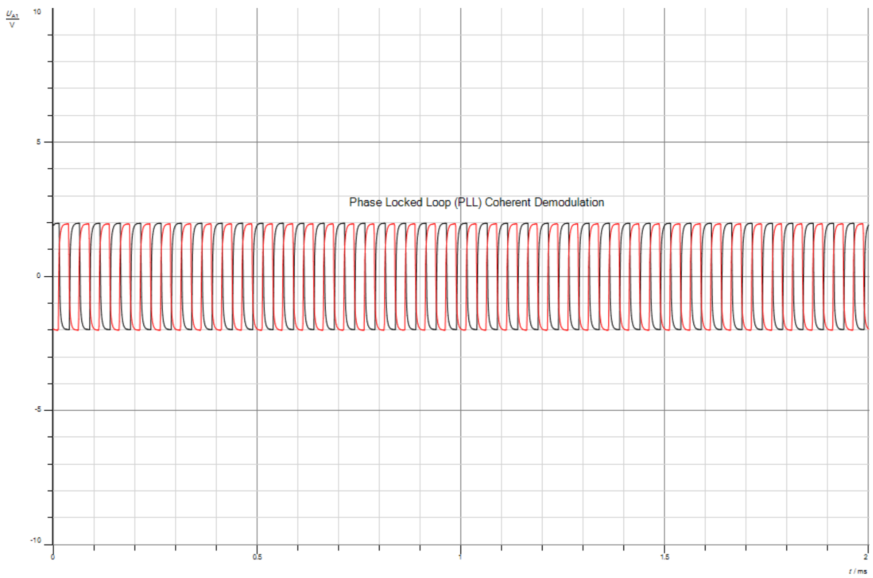

Figure 2.17: Phase Locked Loop (PLL) Coherent Demodulation

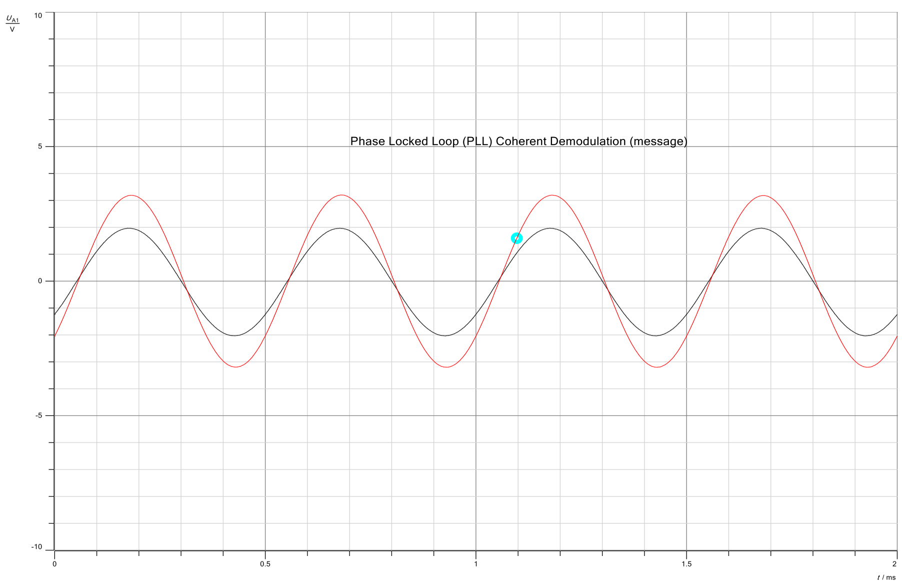

Figure 2.18: Phase Locked Loop (PLL) Coherent Demodulation

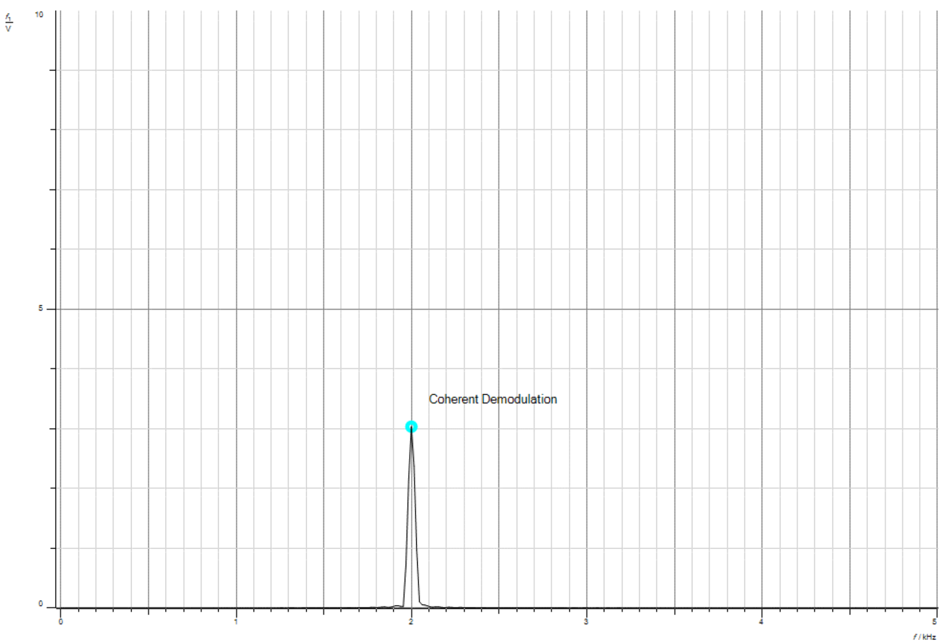

Figure 2.19: Phase Locked Loop (PLL) Coherent Demodulation

The PPL Method creates a local carrier with the same frequency by using the carrier's pilot frequency.

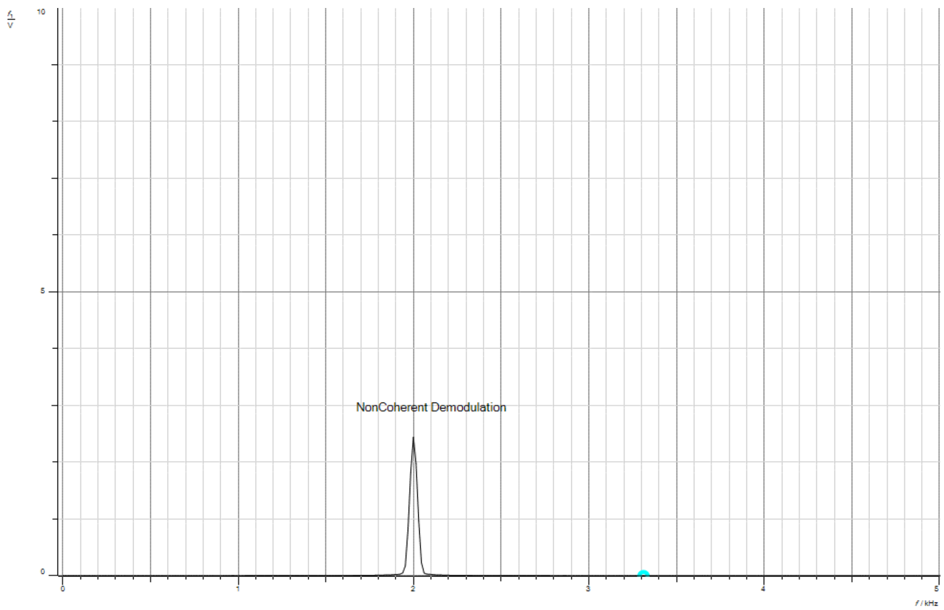

Figure 2.19: Phase Locked Loop (PLL) Coherent Demodulation

dont write the questions. answer them directly through the procedure

3 Questions

Q.1. What do you observe? Will that affect the Modulated signal??

A circuit known as a filter "filters out," or eliminates, a certain range of frequency components. It divides the signal's spectrum into frequency components that will be passed and frequency components that will be blocked, to put it another way. LPF is creates a misalignment between the input signal and the output signal

Q.2. Change the message frequency to 7kHz. What do you observe? Will that affect the Modulated signal?

No while the bandwidth is up to 3,4kHz X, s(t) will be affected, since m(t) will be attenuated due to the filter

Q.3. What is the spectrum of a sinusoidal signal?

A variety of sinusoidal functions or sinusoidal components can be used to describe a signal, which is a function of time.The frequencies, amplitudes, and phases of these sinusoidal components vary.
The Frequency Spectrum or Spectrum of the Signal refers to the plots of frequency vs amplitude and phase for the sinusoidal components that make up the signal.[7]

Q.4. Does the cosine spectrum differ from that of the sine?

yes X

The Fourier Transform, which correlates the time domain function of interest to these basis functions (either cosines and sines or, much simpler, the complex exponential, both with magnitude = 1), is used to first map our time domain function to the frequency domain before representing the frequency spectrum of the function.

Q.5. What is the spectrum of the square train?

The sent signal will be a pulse train as a result of the addition of the various sinusoidal frequencies. The distance between the highest and lowest frequency broadcast determines the breadth of each pulse. The separation between the transmitted frequencies affects the repetition interval. The various frequencies can also be transmitted one at a time and then added together to create a pulse train. This is done via the step frequency radar, which also emits single tone frequencies sequentially, one frequency at a time. The radar reflectivity profile is derived by performing an inverse Fourier transform on the received frequencies, which measures the phase and amplitude of the reflected signal for each frequency

SPACE?!!

dont use we

4 Conclusion

In this experiment, we used the MATLAB and CASSY software to model the modulation and demodulation of AM in the time and frequency domain. We looked at what happened when we changed the modulating signal's amplitude and frequency, both with and without passing it via an LPF. Additionally, we made some computations to determine the modulation index from the data that were actually measured. Finally, we generated a local coherent carrier using the PLL and compared it to the first one.

justify paragraphs

5 References

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