Faculty of Engineering & Technology Electrical & Computer Engineering Department

Communication Lab - ENEE4113

Experiment 2: Double-side and Single-side Band Modulation
Report #2

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Abstract

The main goal of this experiment is to put theoretical understanding of the Double side-band suppressed carrier and Single side band suppressed carrier modulation approaches into practice. In addition to that, this experiment will demonstrate the DSB and SSB modulation schemes, and the results will be shown in the time and frequency domains. Additionally, how altering the message signal frequency and amplitude affects. Moreover, the various types of Single-Sidebands (SSB) modulation include Upper Sideband (USB) and Lower Sideband (LSB). Methods of demodulation will be done in three forms (Coherent, non-coherent and the Phase Locked Loop (PLL) coherent demodulations). Finally, all of the findings will be examined and compared to theoretic predictions.

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Theory

Part one: Double-side Band Suppressed Carrier Amplitude Modulation

At first, I drew a concept map to facilitate understanding of the Double-side band suppressed carrier (DSB-SC), and then I will explain each part separately.

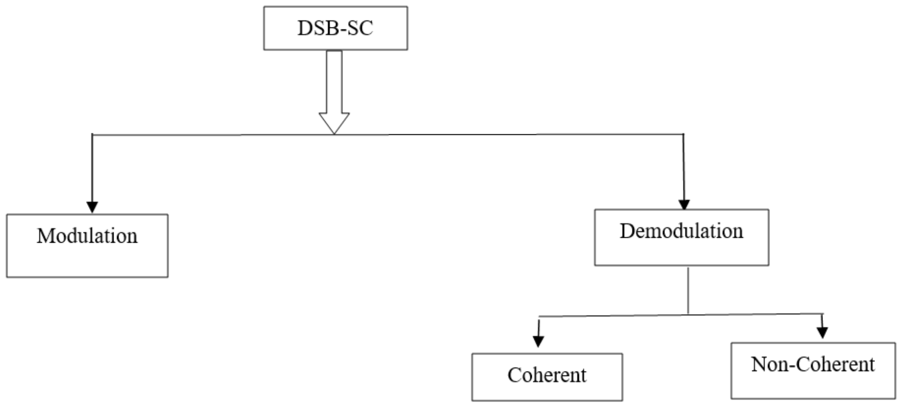

Figure 1: concept map DSB-SC

Modulation (Time and Frequency Domains)

DSB-SC is an amplitude modulated wave transmission scheme in which only sidebands are transmitted and the carrier is not transmitted as it gets suppressed. DSB-SC is an acronym for Double Sideband Suppressed Carrier.[1]

The carrier does not contain any information, the transmission of which would cause a power failure. Therefore, only the sidebands containing information are transmitted. This saves energy during transmission.[1]

Mathematical Representation of DSB-SC modulation

$$s(t) = A_c m(t) \cos(2\Pi f_c t)$$

Where:

- s(t): is the modulated signal.
- m(t): is the message signal.

Generation of DSB-SC signal

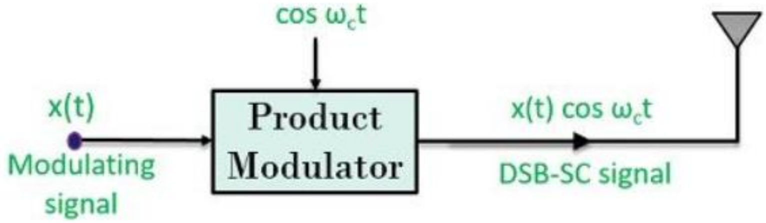

Figure 2: Generation of DSB-SC signal

Here, by observing the above figure, we can say that a product modulator generates a DSB-SC signal. The signal is obtained by the multiplication of baseband signal x(t) with carrier signal cos ωct.

Demodulation of DSB-SC

The process of extracting the original message signal from the DSBSC wave is called detection or demodulation of DSBSC

Coherent Demodulation of DSB-SC

For DSBSC, Coherent Demodulation is done by multiplying the DSB-SC signal with the carrier signal (with the same phase as in the modulation process) just like the modulation process. This resultant signal is then passed through a low pass filter to produce a scaled version of the original message signal.[2]

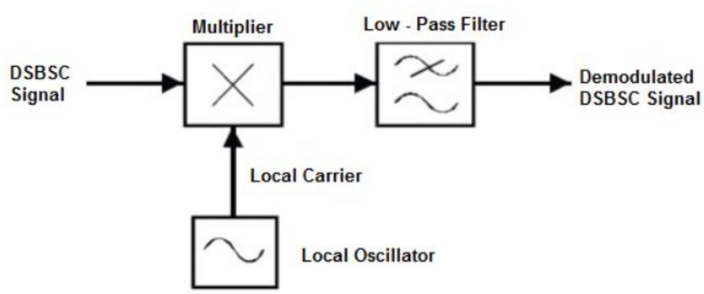

Figure 3: Coherent Demodulation of DSB-SC

Non- Coherent Demodulation of DSB-SC

This means the receiver does not need to phase lock with the carrier frequency. Only full carrier signals can be noncoherently demodulated. Noncoherent will work with any full carrier signal except for independent sideband. For that, we need to use coherent demodulation. But for all of the others (single sideband, double sideband, vestigial sideband), noncoherent will work. [3]

Mathematical Representation of DSB-SC Demodulation

$$v(t) = Ac\, s(t) cos(2\pi f_c t)$$

Where:

- s(t) is the modulated DSB-SC signal
- v(t) is the output waveform.

The modulated signal is then passed through a bandpass filter with a center frequency of f_c,denoted as H(ω). The output of the filter can be expressed as:

$r'(t) = r(t) * H(\omega)$, where * denotes the convolution operation

The output of the filter $V_0(t)$ will be a waveform that contains only the original information signal, (message signal) which can be further processed or analyzed as needed.

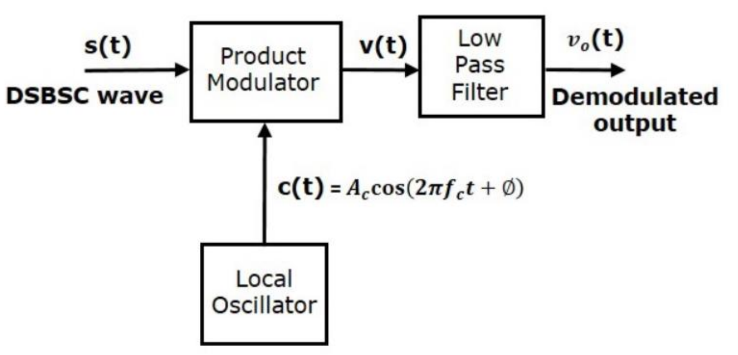

Figure 4:Block Diagram of Demodulation

Part Two: Single-side Band Suppressed Carrier Amplitude Modulation
Single-Sideband Modulation (SSB)

Single side band (SSB) is an amplitude modulation technique in which only one sideband (upper or lower) is transmitted, along with the carrier wave or a suppressed carrier. This method results in a much more efficient use of the available bandwidth than AM or DSB-SC, as only half the bandwidth is required for transmission. SSB modulation can be achieved using a variety of techniques, including frequency-domain filtering or phase-shift modulation.[4]

Mathematical Representation of SSB Modulation
Upper sideband (USB)

$$s(t) = A_C m(t)\cos(2\pi f_C t) - A_C m_{helbert}(t)\sin(2\pi f_C t)$$

Lower sideband (LSB)

$$s(t) = A_C m(t)\cos(2\pi f_C t) + A_C m_{helbert}(t)\sin(2\pi f_C t)$$

Generation of SSB signal

SSB modulation can be generated by filtering the undesired side band of a DSBSC signal and retaining the desired one using a bandpass filter with bandwidth equal that of the message signal (not twice its bandwidth) and a center frequency equal to the center frequency of the desired side band (not the carrier).

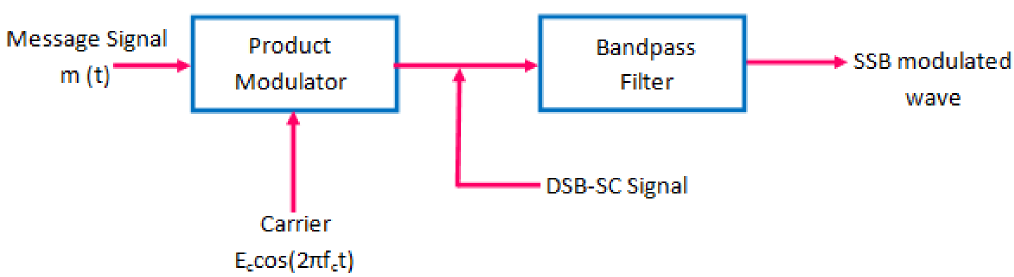

Figure 5: Generation of SSB signal

Demodulation of SSB

The sideband at the positive and negative frequencies merge (recombine) at zero frequency when the SSB signal is multiplied by the carrier.

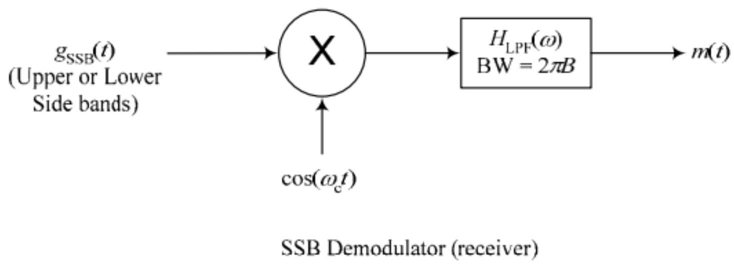

Figure 6: Demodulation of SSB

If the SSB signal includes a LARGE carrier, it can be demodulated using an envelope detector similar to that used for full AM signals

The phase-locked loop (PLL) technology

A phase-locked loop (PLL) is an electronic circuit with a voltage or voltage-driven oscillator that constantly adjusts to match the frequency of an input signal. PLLs are used to generate, stabilize, modulate, demodulate, filter or recover a signal from a "noisy" communications channel where data has been interrupted.[5]

The main goal of a PLL is to synchronize the output oscillator signal with a reference signal. Even if the two signals have the same frequency, their peaks and troughs may not occur in the same place. Simply put, they do not reach the same point on the waveform at the same time.[5]

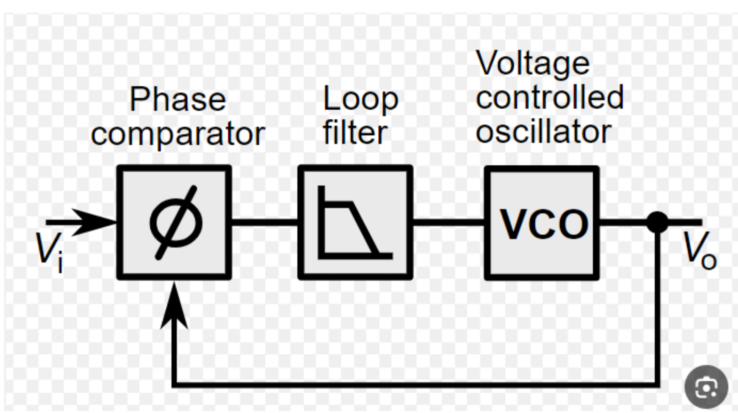

Figure 7: phase locked loop

Procedure, Data analysis and Discussion

Part one: Double-side band suppressed carrier amplitude Modulation

Section 1.1: Modulation (Time and Frequency domains)

At first, the components were connected as shown in figure 8.

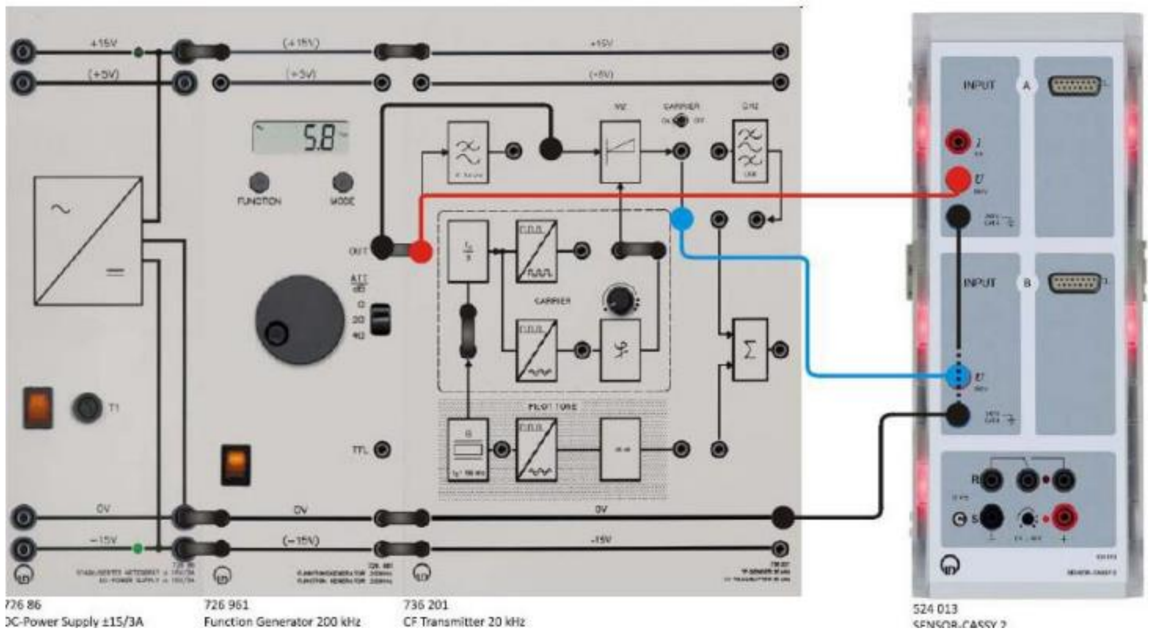

Figure 8: components connection for DSB-SC modulation

After that, the toggle switch was set to CARRIER OFF (this is done to neglect the carrier sum after multiplying the message and carrier) in order to generate the modulated signal (s(t)).

$$s(t) = m(t)c(t)$$

Time and frequency Domain

A sinusoidal message with a voltage of 4V and a frequency of 2 kHz will be used for the DSB message signal.

- Plot the modulator (s(t)) and the message signal (m(t)) at the same time:

  In this part the output signal of the modulator (s(t)) and the message signal (m(t)) was be plotted simultaneously on the Cassy Lab wave as shown in figure

Time Domine:

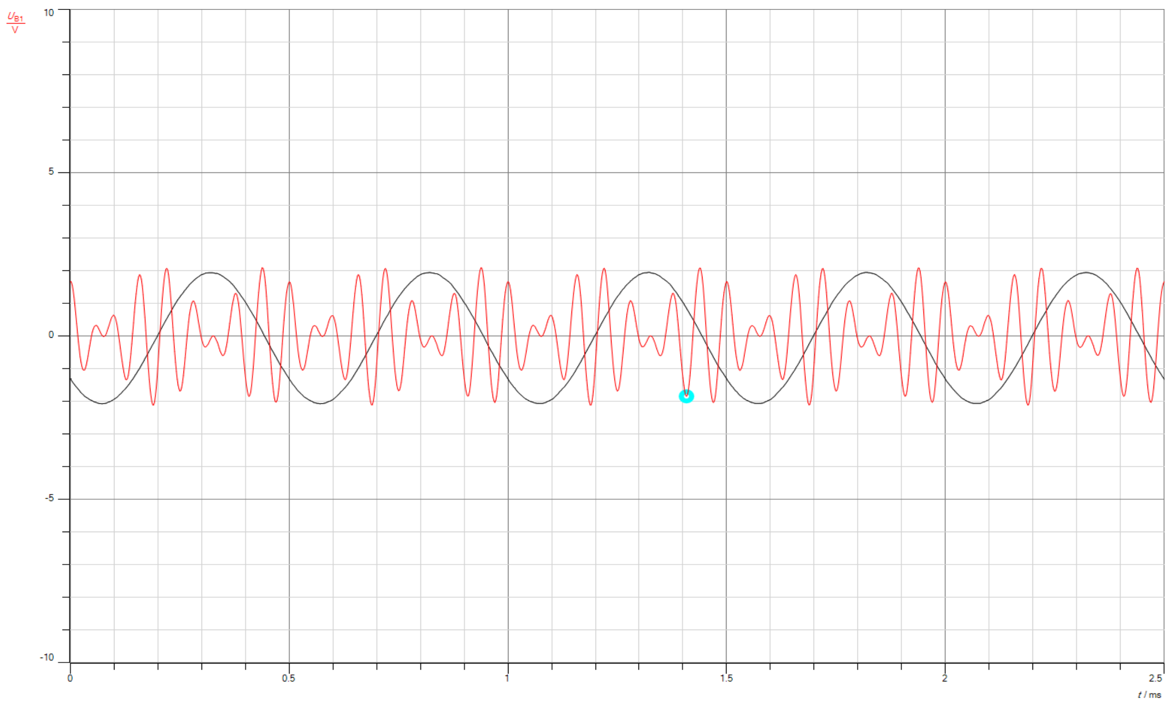

Figure 9:m(t) and s(t) in Time Domine

The red signal indicates to the message signal m(t), and the black signal indicates to modulated signal s(t).

The equation of message signal:

$$m(t) = A_m \cos(2\pi f_m t)$$

Given VSS = 4V so A_m= 2, $f_m = 2kHz$

$$m(t) = 2\cos(2\pi(2k)\quad t)$$

In Figure 9, the amplitude of the message signal is observed to be 2, resembling the amplitude present in the equation.

Frequency domain:

The modulated signal s(f) was plotted in the frequency domain as shown in the figure 10.

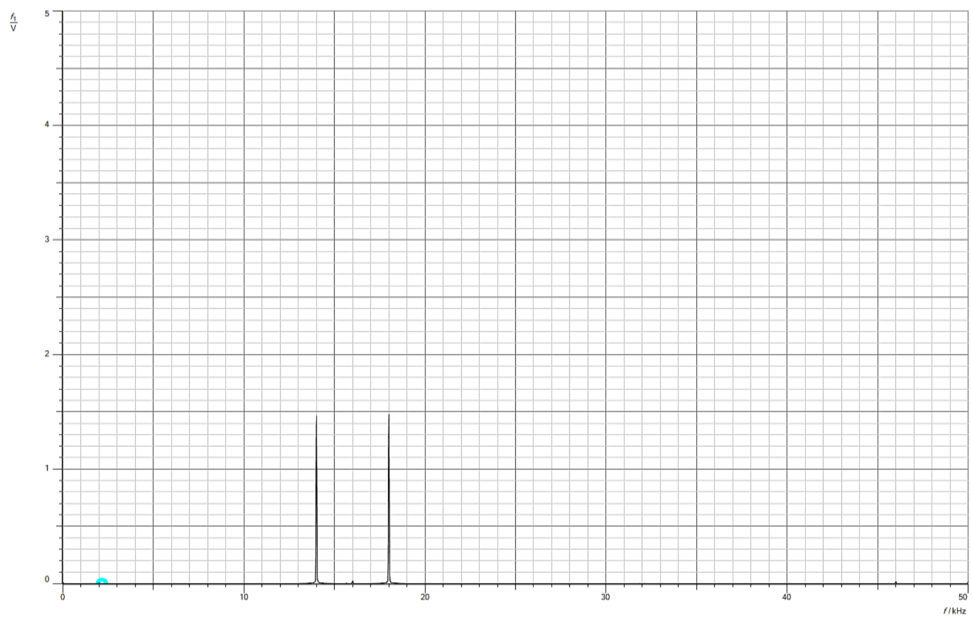

Figure 10: modulated signal s(t) in the frequency domain

Message signal in Frequency domine:

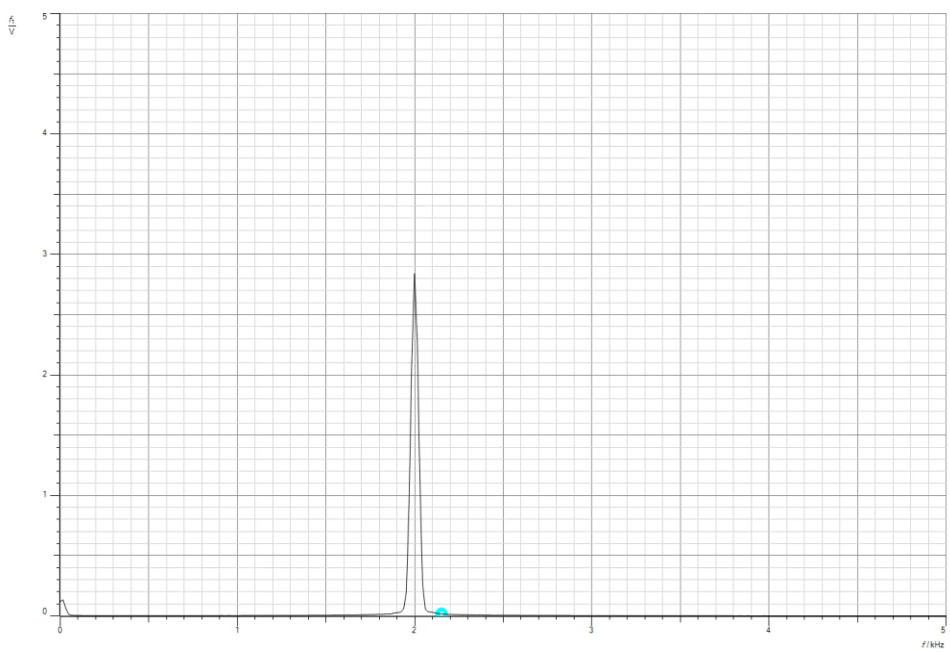

Figure 11:Message signal in Frequency domine

Discussion

The carrier generated from the kit itself, generating at 160 Hz, from the kit 160Hz /10=16 Hz, So the frequency of carrier is 16 Hz. Also, given f_m=2kHz, according to the figure we have two delta one at f_c+f_m=18, and another at f_c-f_m=14. In addition to that, the band width (BW) = 18-14 =4 Hz according to figure 10, and the power efficiency equals 100% because only the sidebands are transmitted without the carrier.

Mathematically, if the message signal is represented by:

$$m(t) = A_m \cos(2\pi f_m t)$$

And the carrier signal is represented by:

$$c(t) = A_c \cos(2\pi f_{mc} t)$$

Then the modulated signal can be expressed as:

$$s(t) = m(t) * c(t)$$

$$s(t) \ = \ Am \ Ac \ /2 \ * \ cos[2 \ pi \ (fc - fm)t] \ + \ Am \ Ac \ /2 \ * \ cos[2 \ pi \ (fc - fm)t]$$

Through these equations, we note that the modulated signal s(t) and has amplitude AmAc/2, and its envelope is the message signal (m(t)).

The effect of changing The Frequency of the message signal

- In this part, Vss is kept at 4V, and the message frequency is changed to 1kHz.

Time domine:

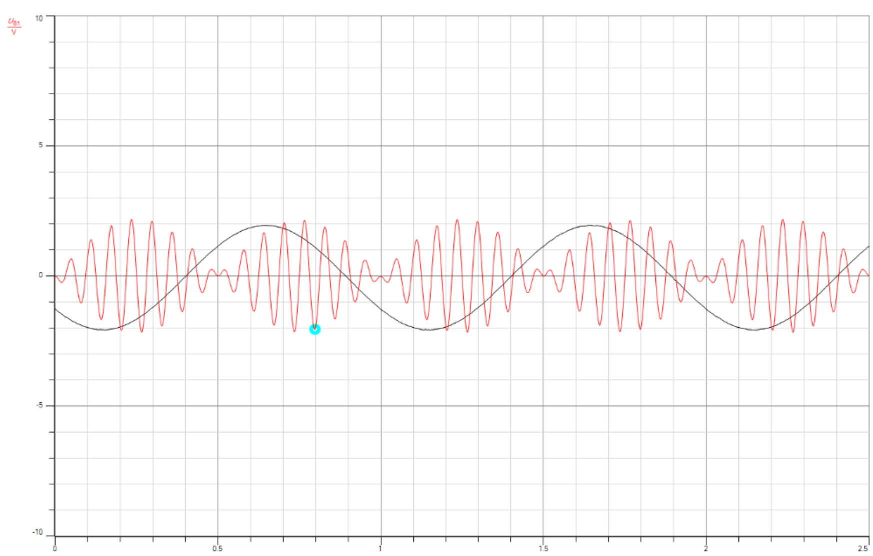

Figure 12: s(t) and m(t) in time domine when fm=1k, Vss=4v

Modulated signal s(f) in Frequency domine:

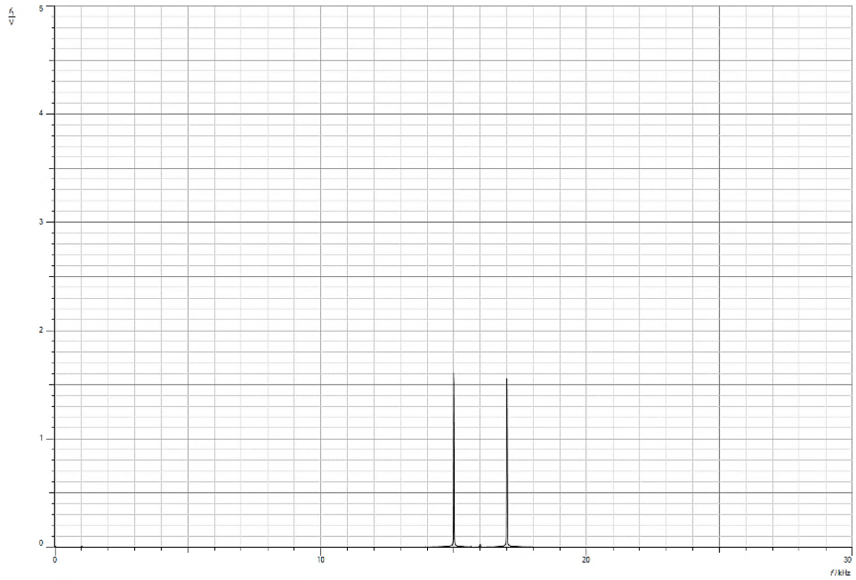

Figure 13: Modulated signal s(f) in Frequency domine when fm=1kHz, Vss=4v

From the figure 13 the bandwidth (BW) =$(f_C + f_m) - (f_C - f_m) = 17 - 15 = 2kHz$

Discussion

The figure 12 show m(t) and s(t) in time domine, the modulated signal s(t) in red color has amplitude "AmAc/2”, and its envelope is the message signal (m(t)).

The figure 13 shows the spectrum of s(f) it’s appeared as two deltas represent the upper side band and the lower side band that are almost equal in the amplitude. In the frequency domain (f1=fc+fm) =17 KHz, (f2=fc-fm) =15 and has amplitude AmAc/2.

- In this part, Vss is kept at 4V, and the message frequency is changed to 3kHz.

Time domine:

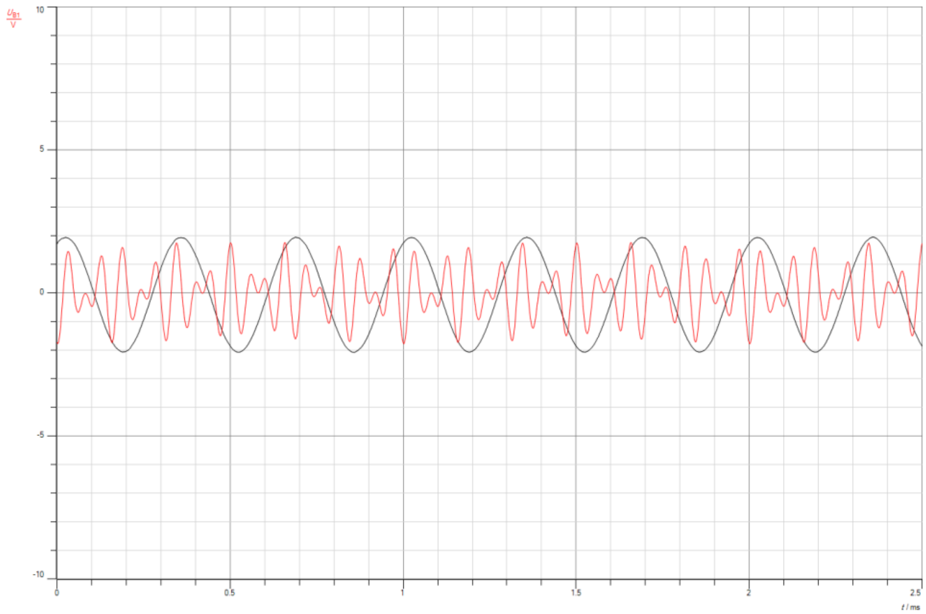

Figure 14: : s(t) and m(t) in time domine when fm=2kHz, Vss=4v

Modulated signal s(f) in Frequency domine:

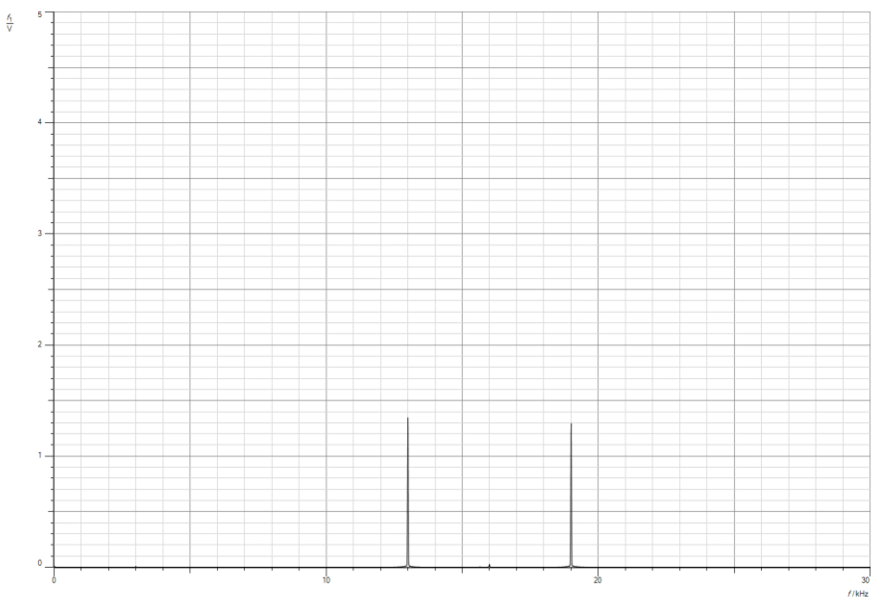

Figure 15: Modulated signal s(f) in Frequency domine when fm=3kHz, Vss=4v

From the figure 13 the bandwidth (BW) =$(f_C + f_m) - (f_C - f_m) = 19 - 13 = 6kHz$

Discussion

when the message frequency from 1kHz to 3kHz, the bandwidth of the modulated signal will also increase. In DSB-SC AM, the total power is divided equally between the upper and lower sidebands. Changing the message frequency won't affect the power distribution between the sidebands. However, higher message frequency will distribute this power over a wider frequency range.

When f_m was increase or decrease, the carrier signal's envelope and frequency remained unaffected, but the waves of the envelop for the massage and DSB signals moved closer together when f_m was decreased and further apart when it was increased.

The DSB signal frequency changed as shown below:

- For (f_m = 1k) => (f_c-f_m, f_c+f_m) => (15kHz, 17kHz)
- For (f_m = 3k) => (f_c-f_m, f_c+f_m) => (13k, 19k)

The Effect of Changing the Amplitude

- In this part f_m is kept 2kHz and the message Vss is changed to 2V

Time domine:

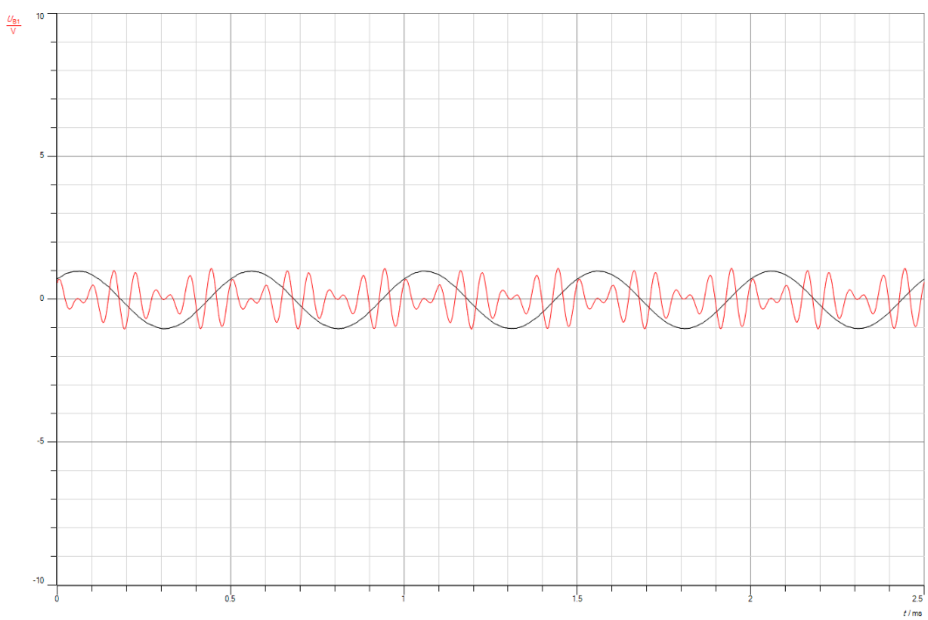

Figure 16: m(t) and s(t) in time domine when fm=2k, Vss=2v

Modulated signal s(f) in Frequency domine:

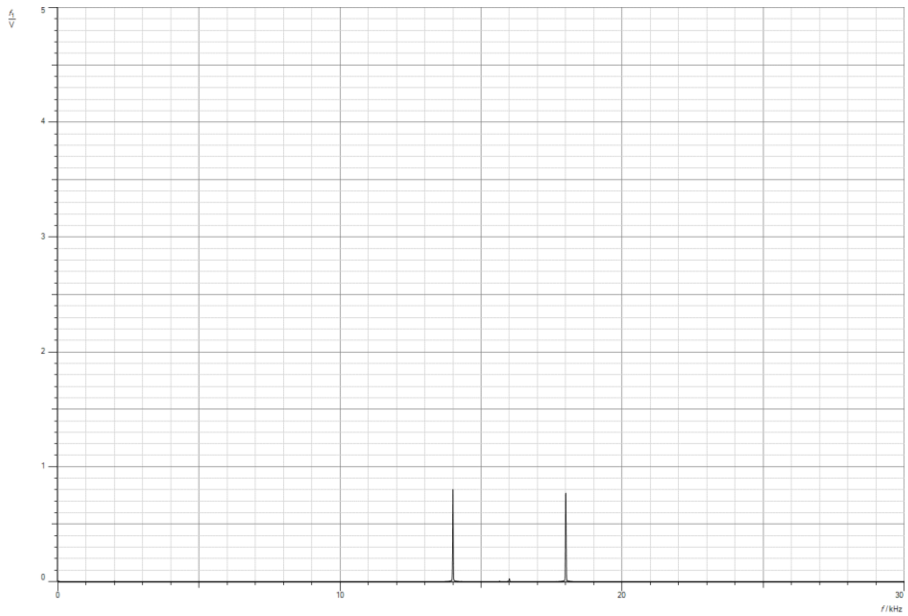

Figure 17: s(t) in in Frequency domine when fm=2k, Vss=2v

The bandwidth is 4kHz, and the power efficiency equals 100% because we only transmit the sidebands without the carrier

Discussion

The figure 16 show m(t) and s(t) in time domine, the modulated signal s(t) in red color has amplitude "AmAc/2", and its envelope is the message signal (m(t)).

The figure 17 shows the spectrum of s(f) it's appeared as two deltas represent the upper side band and the lower side band that are almost equal in the amplitude. In the frequency domain (f1=fc+fm) =18 KHz, (f2=fc-fm) =14 and has amplitude AmAc/2.

- In this part f_m is kept 2kHz and the message Vss is changed to 6V

  Time Domine:

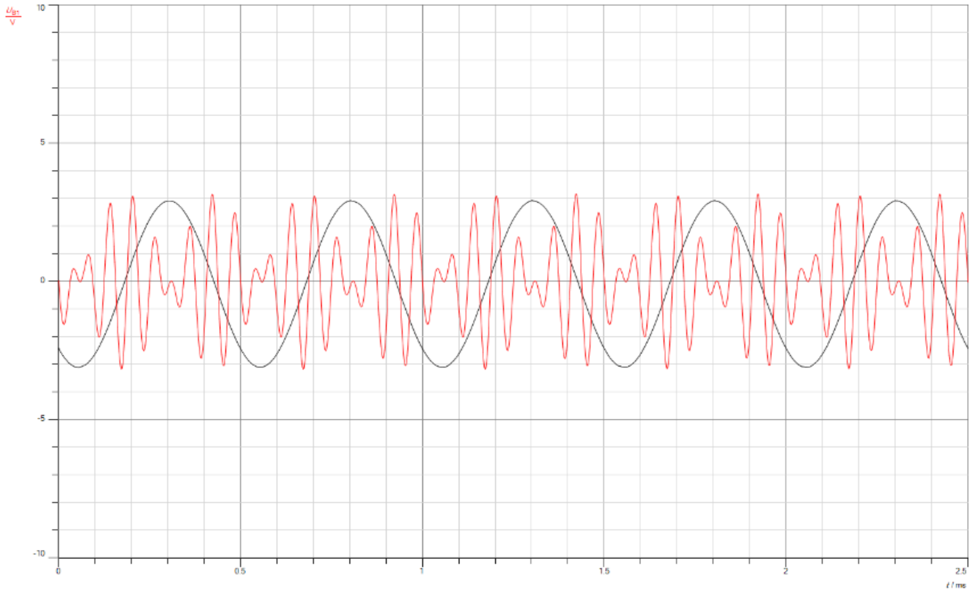

Figure 18: m(t) and s(t) in time domine when fm=2k, Vss=6v

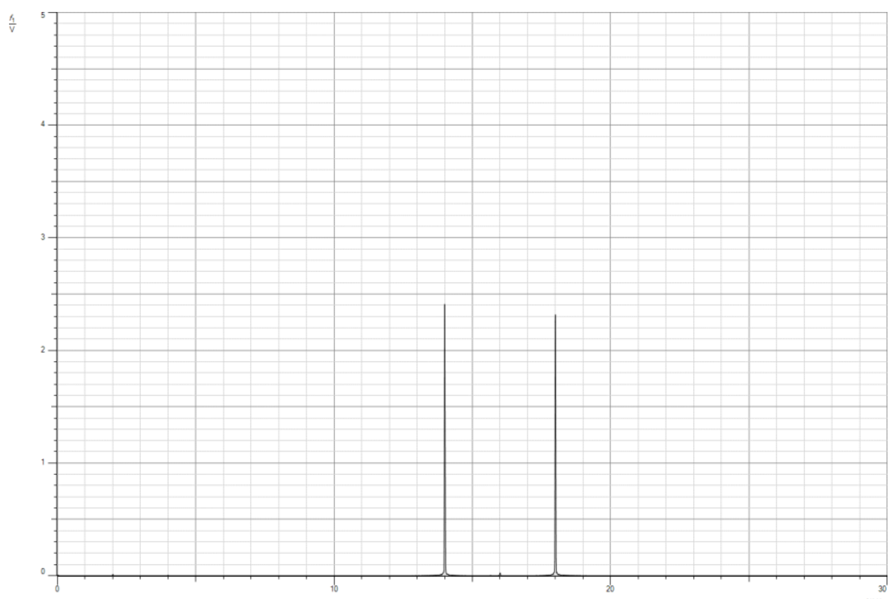

Figure 19: s(t) in in Frequency domine when fm=2k, Vss=2v

The bandwidth is 4kHz, and the power efficiency equals 100% because we only transmit the sidebands without the carrier

Discussion

Increasing the amplitude of the message signal increases the amplitude of the upper and lower sidebands of the modulated signal proportionally.

The total power of the DSB-SC AM signal is proportional to the square of the amplitude of the modulating signal. Doubling the message amplitude from 2V to 6V results in a quadrupling of the signal power.

Keep in mind that the carrier signal is suppressed in DSB-SC AM, so the power calculations are directly related to the amplitudes of the sidebands.

Increasing the message amplitude increases the modulation index. This can lead to more efficient modulation where a higher percentage of the carrier power is used to transmit the message signal.

Compare the results from the two observations

The location of the upper sideband impulse on the frequency spectrum changes as the signal frequency fm changes. The frequency of the upper sideband (f1) is the product of the carrier frequency (fc) and the message frequency (fm). Therefore, the location of the upper sideband impulse on the frequency axis will shift correspondingly as the message frequency varies. Upper sideband frequency (f1) is calculated as follows: carrier frequency (fc) + message frequency (fm).

The lower sideband is positioned at a frequency equal to the difference between the carrier frequency fc and the message frequency fm (f2 = fc - fm). Consequently, as the message frequency varies, the lower sideband impulse's location on the frequency spectrum adjusts proportionally. Mathematically: Lower sideband frequency (f2) = Carrier frequency (fc) - Message frequency (fm).

The bandwidth of the modulated signal in Double Sideband Suppressed Carrier (DSB-SC) modulation depends on the bandwidth of the modulating signal. In DSB-SC modulation, the modulating signal for a typical Amplitude Modulation (AM) transmission is a baseband signal, which normally has a bandwidth ranging from zero hertz to a maximum frequency f_max. BW = 2fm then yields the AM signal's bandwidth.

The bandwidth of the modulated signal in Double Sideband Suppressed Carrier (DSB-SC) modulation depends on the bandwidth of the modulating signal. In DSB-SC modulation, the modulating signal for a typical Amplitude Modulation (AM) transmission is a baseband signal, which normally has a bandwidth ranging from zero hertz to a maximum frequency f_max. BW = 2fm then yields the AM signal's bandwidth.

- Power of carrier signal = 0, there are no carrier in DSBsc.
- Power of 2 side Bands = $(Ac\ \mu/ 2)^2$
- Efficiency = $(2\ Psides\ /\ Ptotal)\ *\ 100\%$

$$= ((Ac\ \mu/ 2)^2\ )\ /\ (((Ac\ \mu/ 2)^2\ +\ 0\ )\ * 100\%\ =\ 100\ \%$$

Demodulation (Time and frequency domains)

Coherent Demodulation

At first, the components were connected as shown in figure 20. And the function generator is set to: sine, VSS = 4V and fm = 2 kHz.

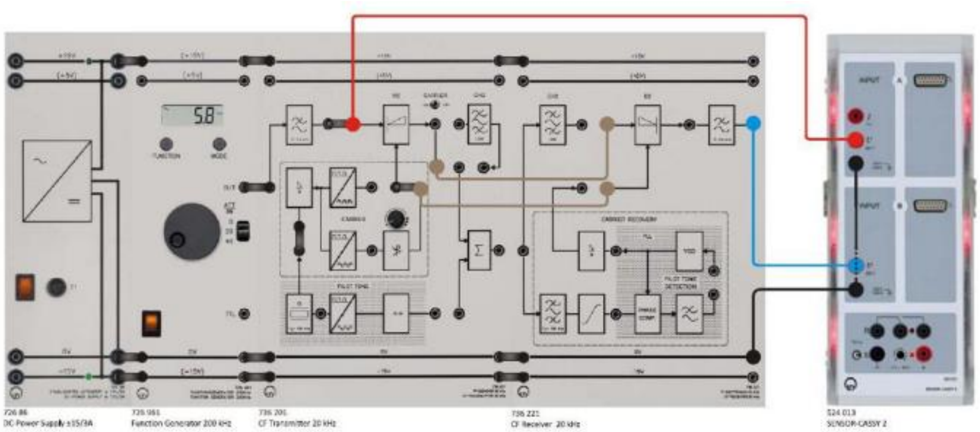

Figure 20: components connection for DSB-SC Coherent Demodulation

The phase controller (φ) is to be set to the leftmost position (Minimum value = 0°). The s(t) signal should be directly fed into the demodulator, and no filter is to be employed during its transmission. A sinusoidal carrier signal is to be introduced into the auxiliary carrier input of the demodulator using a wire.

The two signals are multiplied at the input of the product modulator, and the output signal is then routed through a low pass filter with a bandwidth equal to fm. The modulating signal is present once again at the filter's output.

$$r(t) \; = \; s(t) \; Ac` \; cos(2\pi f c t)$$

Only the first term will pass through the filter when r(t) is applied, rejecting all other undesirable words. As a result, the scaled message signal will be received at the filter's output, and coherent DSB demodulation will be accomplished, as illustrated in the following figure. Although this approach is thought to be successful, energy is used.

Time Domine:

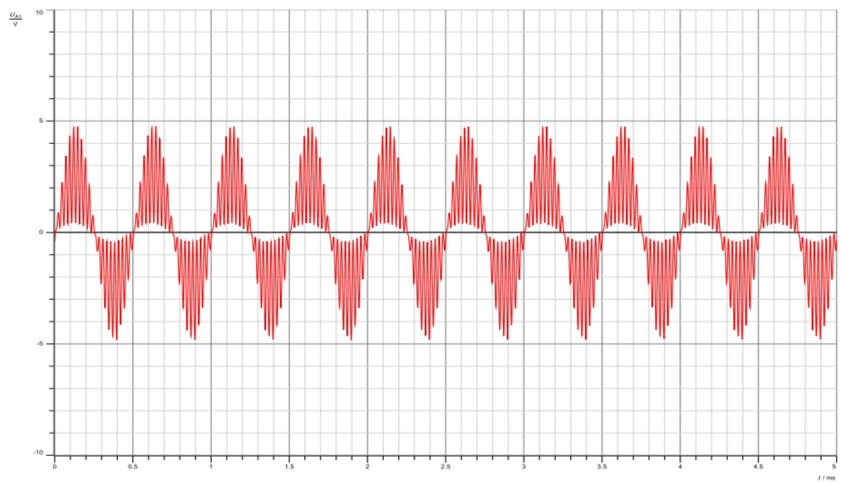

Figure 21: m (t) and s(t) in time domain before filter

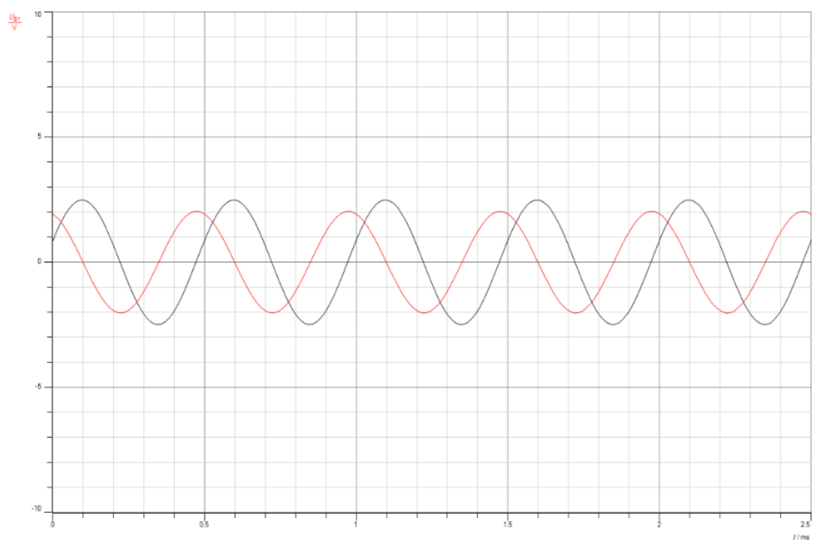

Figure 22: m (t) and s(t) in time domain after filter

It noted that the coherent demodulation results in a large number of harmonics. As shown in figure 21, this method included a filter to reject any more undesired words and create a phase shift 90, as shown in figure 22.

Frequency Domain:

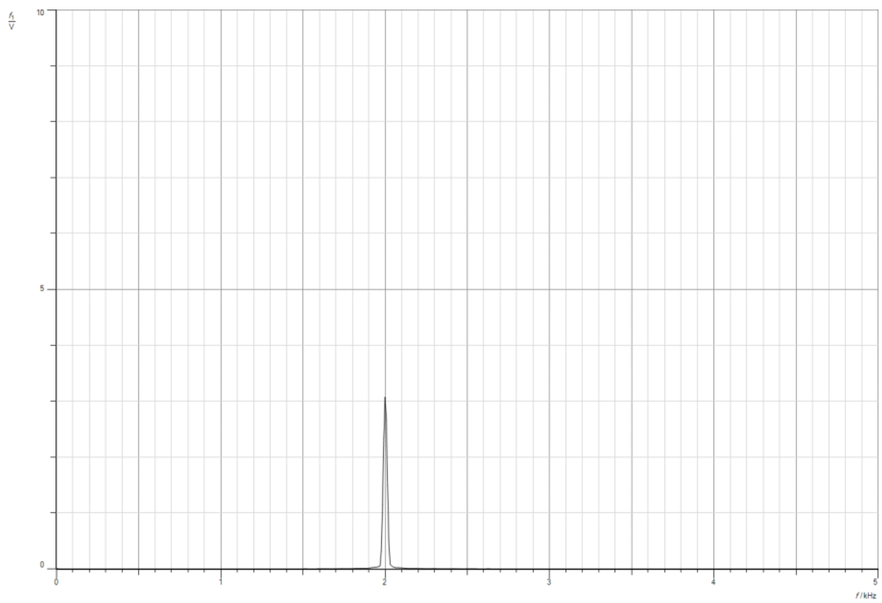

Figure 23: spectrum of the coherent demodulated signal

Frequency Domain: As shown in figure 23 it will get the original massage signal at frequency fm=2kHz after the Demodulation process.

In communication systems, a receiver output filter also called a demodulator filter is used to control the output waveform of a demodulator or detector. It increases the overall quality of the received signal by removing high-frequency components, lowering noise, and serving various other objectives.

Mathematically, the output filter can be represented as a lowpass filter with a cutoff frequency that is equal to the bandwidth of the message signal. The filter will remove any high frequency components that are outside the cutoff frequency, effectively isolating the message signal and preventing interference from high frequency component.

Non-Coherent Demodulation

Time Domine:
When Phase shift =0

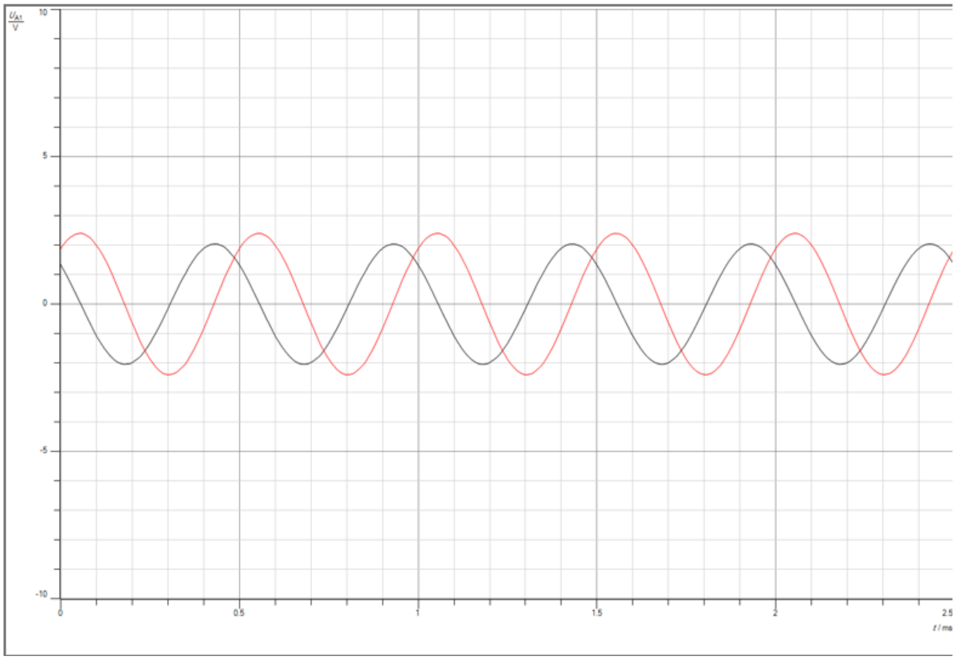

Figure 24: Noncoherent Demodulation Signal When Phase shift =0

When Phase shift =90

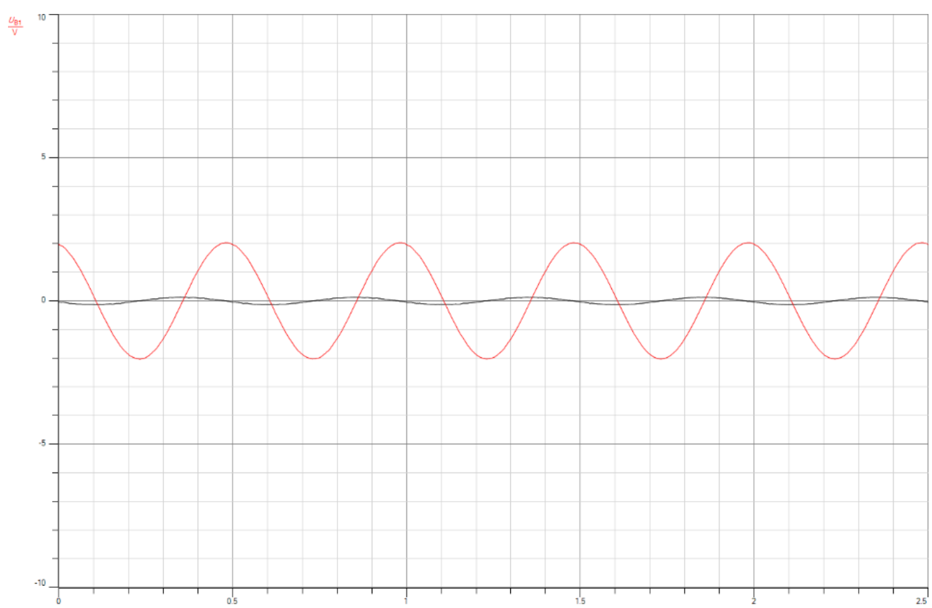

Figure 25: Noncoherent Demodulation Signal When Phase shift =90

Freqancy domine:
When Phase shift =0

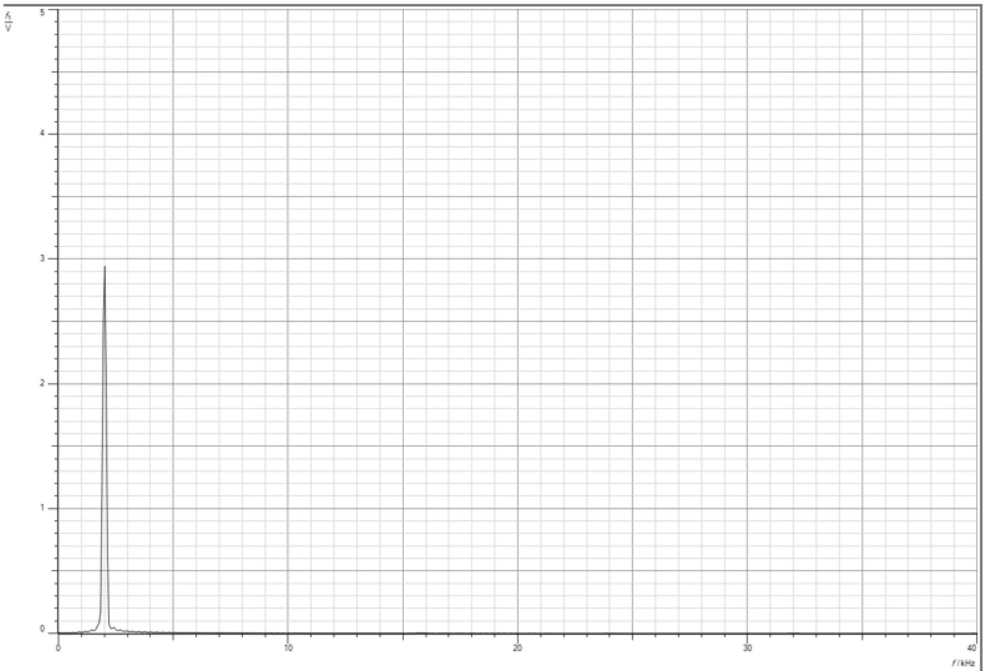

Figure 26:spectrum of modulated signal When Phase shift =0

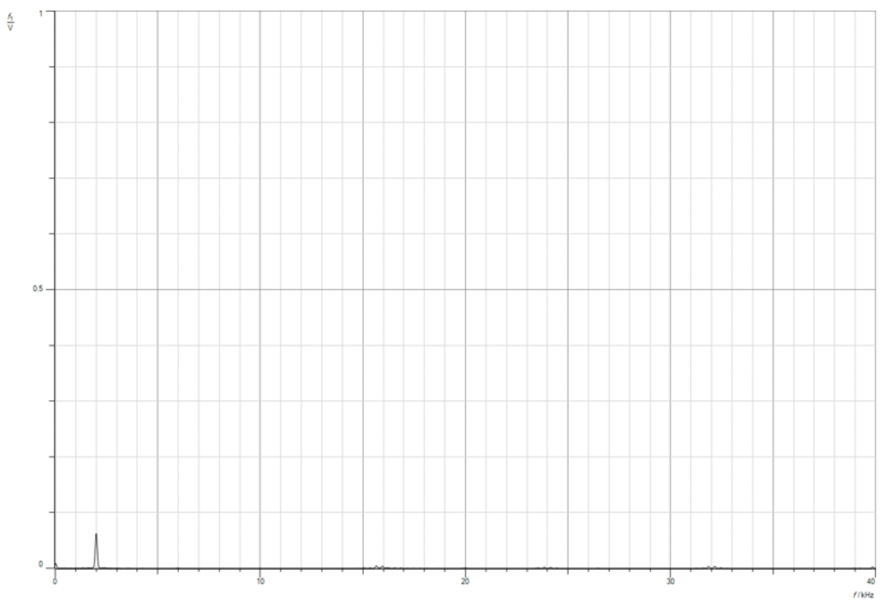

Figure 27: spectrum of modulated signal When Phase shift =90

We fed a sinusoidal carrier from the pin before the phase shifter to the modulator to explore the impact of non-coherence, and we fed a sinusoidal carrier from the pin after the phase shifter to the demodulator.

From the phase shifter (φ), we changed the carrier phase. And note that as the angle reached 90 degrees, we lost the signal.

Part Two: Single-Side Band Suppressed Carrier Amplitude Modulation Modulation (Time and frequency domains)

At first, the components were connected as shown in figure 28.

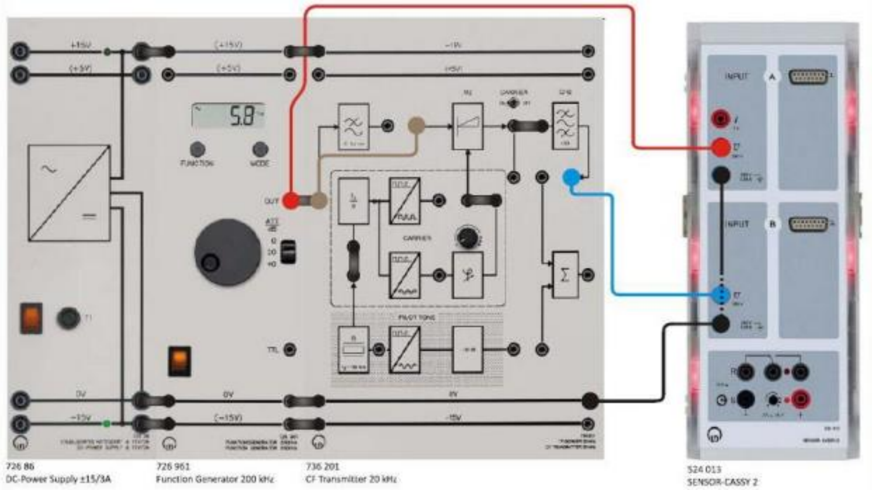

Figure 28:SSB-SC modulation connection

After that, the toggle switch was set to CARRIER OFF is a key step in implementing Single Sideband Suppressed Carrier (SSB-SC) modulation. Means that the carrier wave is suppressed in the modulated signal, resulting in a single-sideband with suppressed carrier (SSB-SC) modulation.

When the carrier switch is turned on in SSB-SC modulation, the carrier wave is included into the modulated signal. A double-sideband signal with suppressed carrier (DSB-SC) modulation is the end consequence of this. On the other hand, turning the carrier switch off results in a single-sideband with suppressed carrier (SSBSC) modulation, which suppresses the carrier wave in the modulated signal.

As show above in the experiment, the circuit was connected with frequency (Fm) = 2 kHz and Vss = 4V and the carrier switch was off; To increase power efficiency

Time domine:

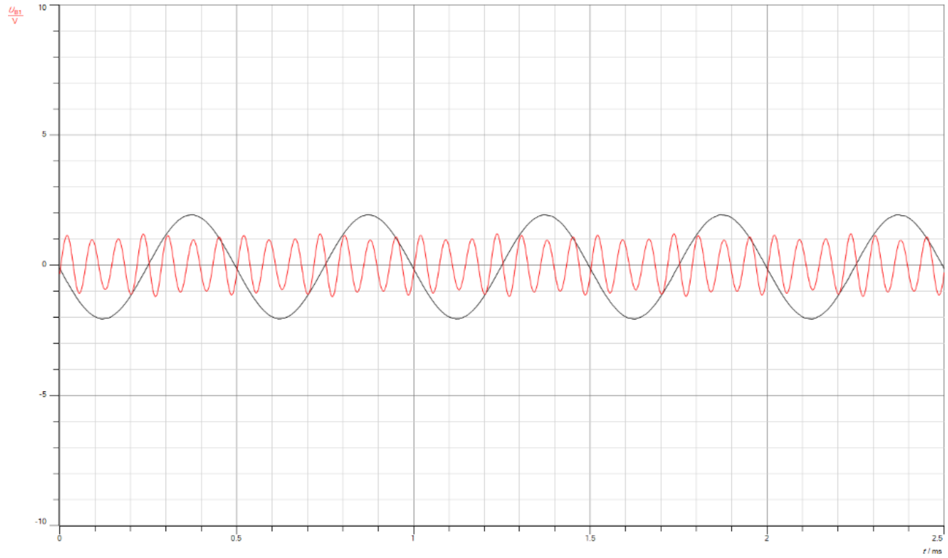

Figure 29: s(t) and m(t) in time domain

Frequency Domain:

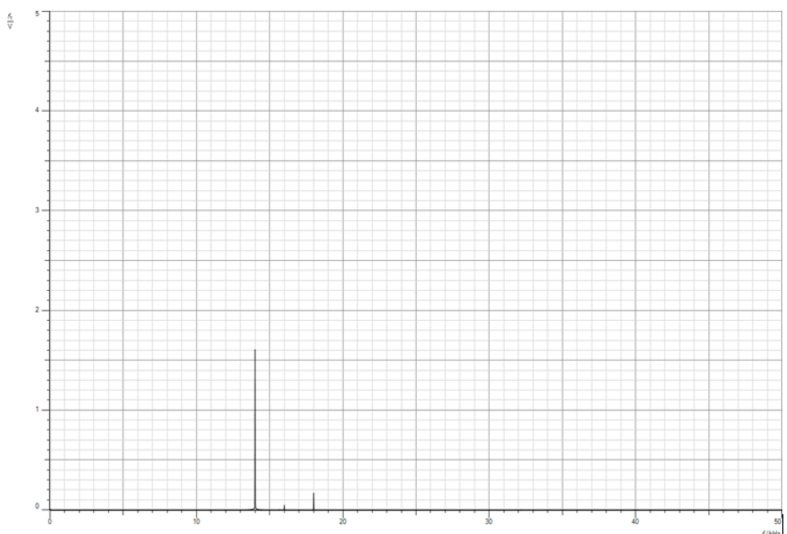

Figure 30: Spectrum of modulated signal Frequency Domain

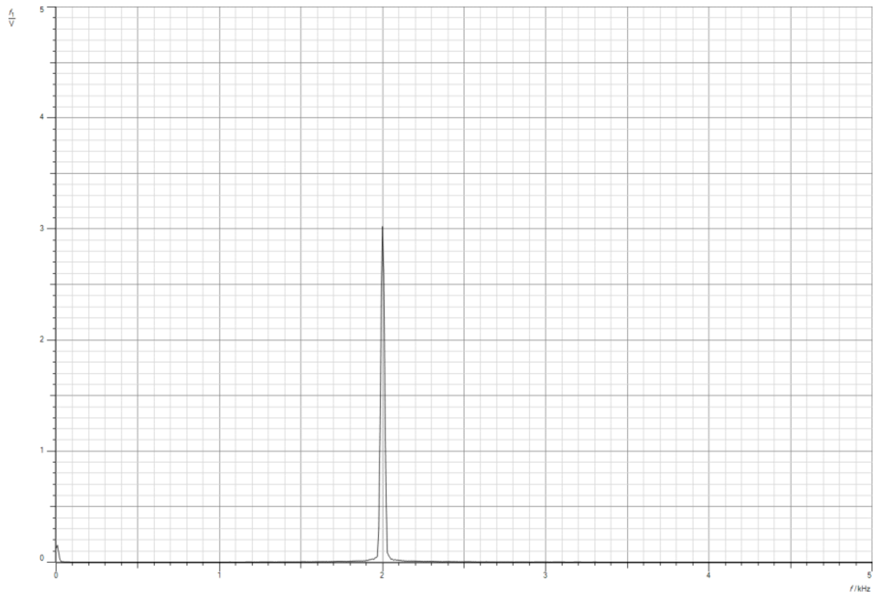

Figure 31: Spectrum of Message signal Frequency Domain

Discussion

The modulated signal in SSB-SC modulation contains data from the message signal. The message signal is a baseband signal that has been modulated onto a radio frequency carrier wave, like an audio signal. SSB-SC, on the other hand, suppresses the carrier wave and only leaves the upper or lower sideband, which contains the modulated message signal. A local oscillator at the receiver can be used to regenerate the carrier wave in order to demodulate the modulated signal. The original message signal is the resultant demodulated signal. In Upper Side SSB-SC, take note that the frequency of the modulated signal is equal to the product of the m(t) and c(t) frequencies.

The effect of changing The Frequency of the message signal

- In this part, v_{ss} is kept at 4V, and the message frequency is changed to 1kHz.

Time domine:

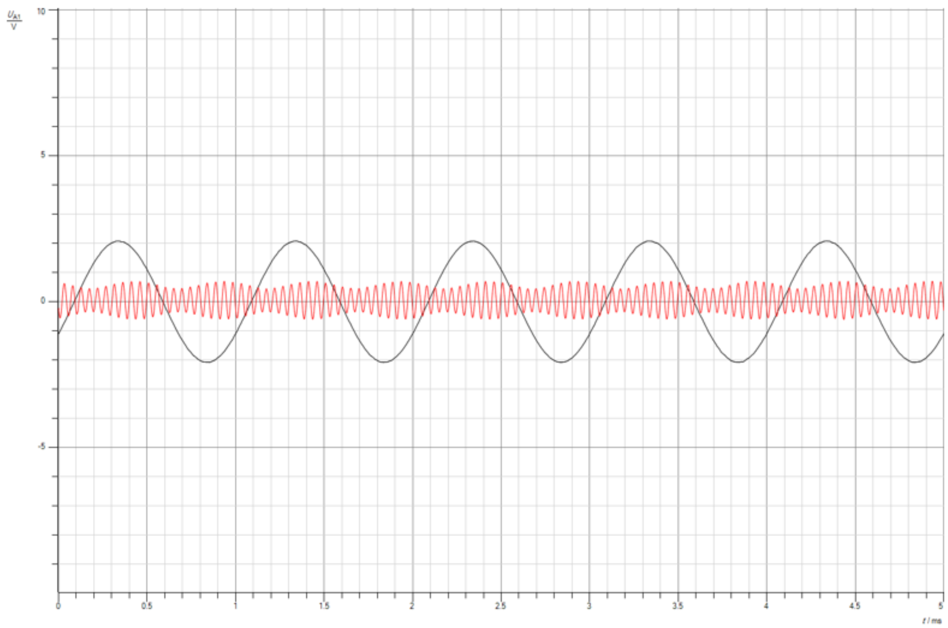

Figure 32: The m(t) and s(t) in time domine when fm=1k, Vss=4v

Frequency Domain:

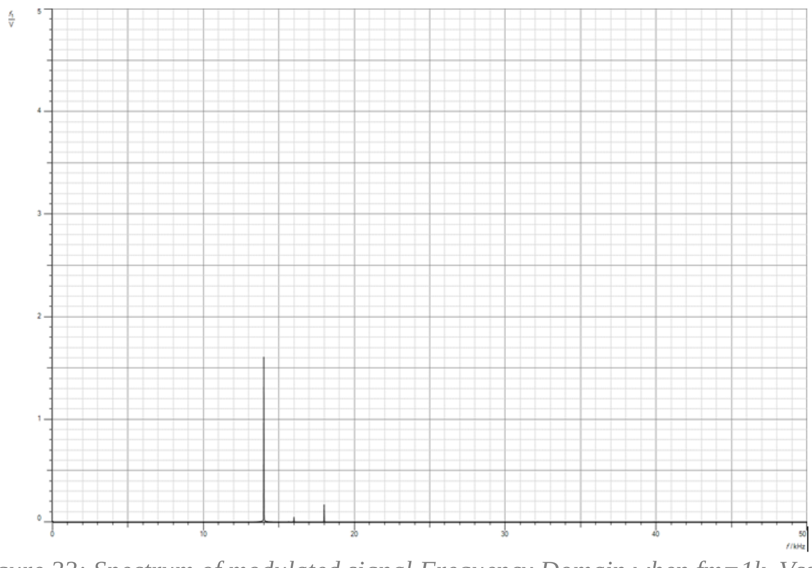

Figure 33: Spectrum of modulated signal Frequency Domain when fm=1k, Vss=4v

As shown of the figure above that the signal coming out, frequency and BW for massage signal was affected f_m=1kh, And decreased amplitude and number of cycles for the massage.

- In this part, v_{ss} is kept at 4V, and the message frequency is changed to 3kHz.

Time domine:

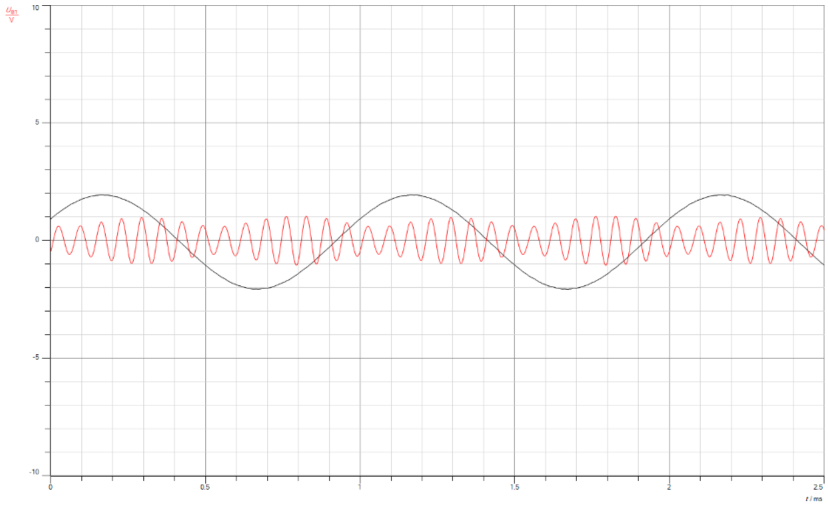

Figure 34: The m(t) and s(t) in time domine when fm=3k, Vss=4v

Frequency Domain:

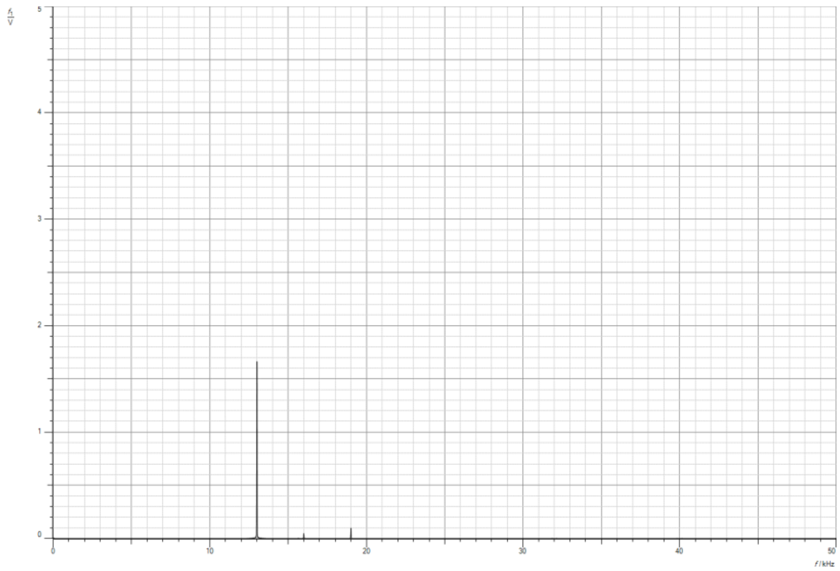

Figure 35: Spectrum of modulated signal Frequency Domain when fm=3k, Vss=4v

Discussion

A message signal with a frequency of 1 KHz will produce a modulated signal with a smaller bandwidth in Upper side SSB-SC modulation than a message signal with a frequency of 2 KHz. When spectral efficiency is low, this smaller bandwidth might be helpful. when many signals must be processed in wireless communication systems, for example. sent at the same time.

As compared to a message signal with a frequency of 2 KHz, a message signal with a frequency of 3 KHz will produce a modulated signal with a larger bandwidth. When a high-quality signal is required, such as in audio applications where the signal must maintain its purity and precision, this broader bandwidth might be useful.

Both times, the carrier wave is suppressed and the upper sideband of the modulated signal is unaffected. To effectively demodulate the signal and retrieve the original message, the receiver must renew the carrier wave.

The effect of changing the amplitude of the message signal

- In this part f_m is kept 2kHz and the message v_{ss} is changed to 2 V

  Time domine:

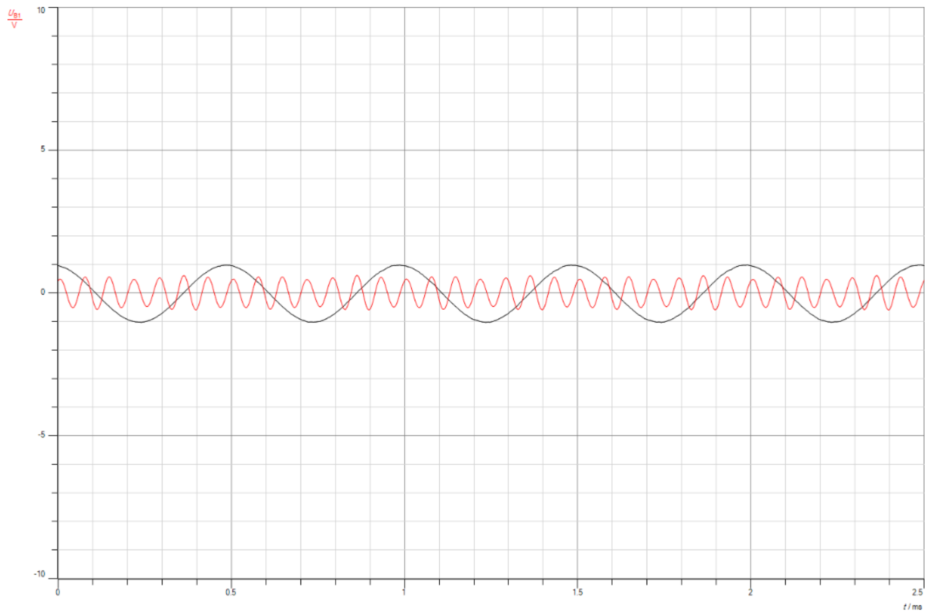

Figure 36: The m(t) and s(t) in time domine when f_m =2k, V_{ss} =2v

Frequency Domain:

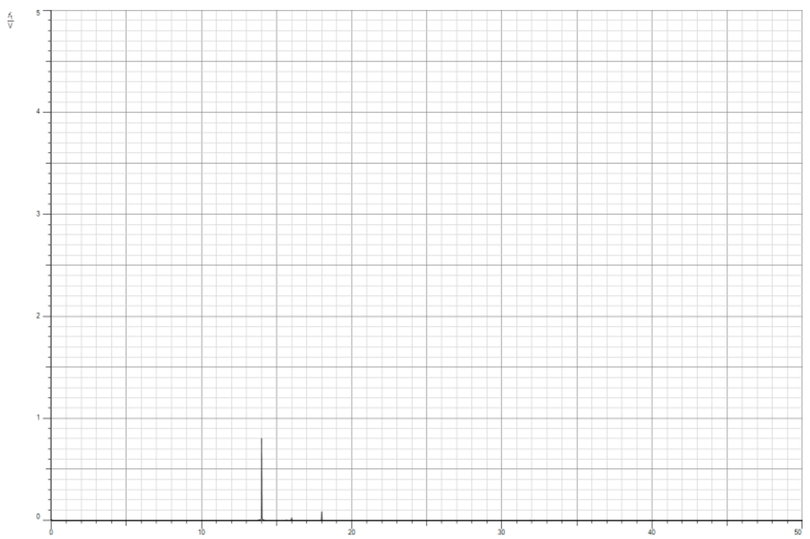

Figure 37: Spectrum of modulated signal Frequency Domain when f_m =2k, V_{ss} =2v

- In this part f_m is kept 2kHz and the message v_{ss} is changed to 6 V

Time domine:

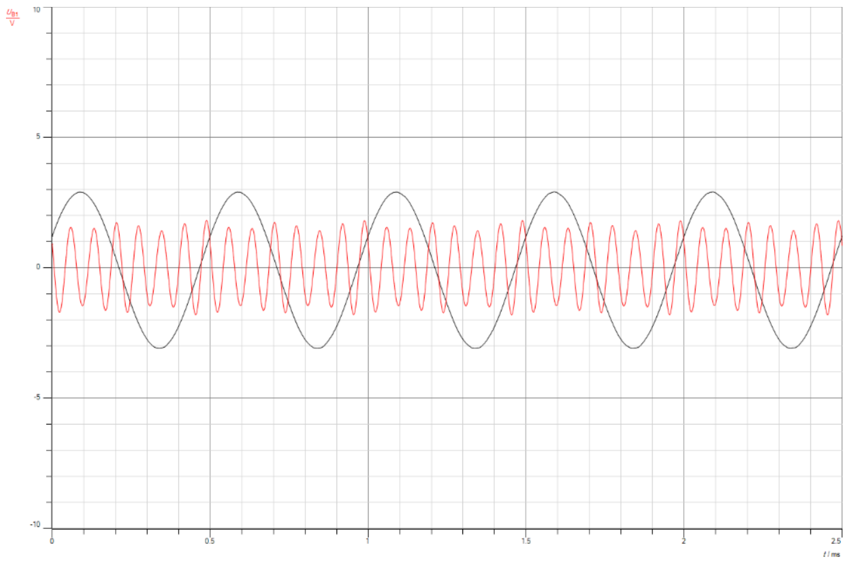

Figure 38: The m(t) and s(t) in time domine when f_m =2k, V_{ss} =6v

Frequency Domain:

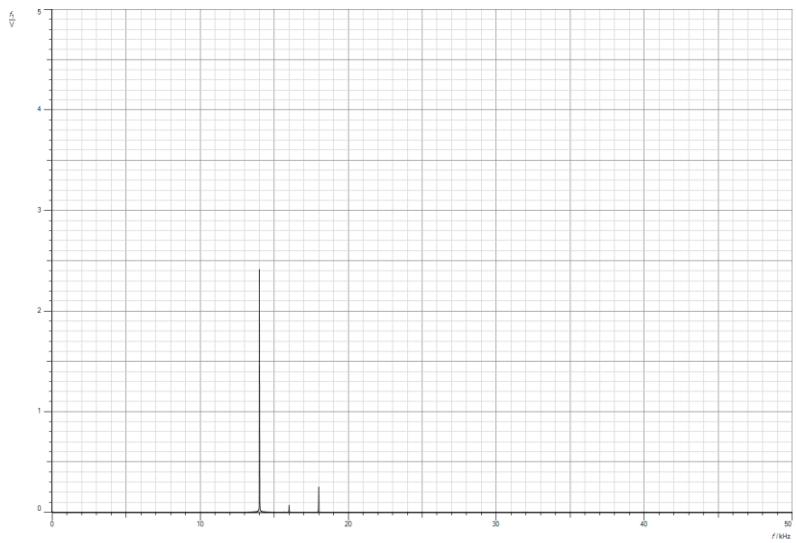

Figure 39: Spectrum of modulated signal Frequency Domain when f_m =2k, V_{ss} =6v

Discussion

The modulated signal's amplitude changes as the message signal's amplitude in Upper side SSB-SC modulation changes. The message signal's amplitude determines the modulated signal's amplitude, which is directly proportional to it. As a result, lowering the message signal from 2 volts (V_{ss} = 4v) to 1 volt (V_{ss} = 2v) will result in a decrease in the modulated signal's amplitude, while raising it to 3 volts (V_{ss} = 6v) will result in an increase.

Changes in message amplitude, however, have no immediate impact on the modulated signal's bandwidth. The carrier wave is still muted, and the modulated signal's upper sideband is unaltered. For the signal to be effectively demodulated and the original message to be recovered, the receiver must renew the carrier wave.

Compare the results from the two observations

As the message signal's frequency rises, the upper side impulse's frequency rises correspondingly but its amplitude stays constant, following a linear relationship with the signal's frequency fm.

The SSB-SC modulation method suppresses the lower side impulse, which results in a considerably smaller amplitude than the upper side impulse. However, its frequency is constant independent of the message frequency and equal to the carrier frequency minus the message frequency.

The difference in frequency between the upper and lower side impulses may be used to calculate the transmission bandwidth of the regular amplitude modulation signal. The transmission bandwidth in SSB-SC modulation is the same as the message frequency, which in the first instance is 2 kHz and in the second case is 3 kHz.

Any message signal that is in the modulator's operating frequency range can be applied the findings and conclusions from this experiment. While the bottom side impulse is repressed, the upper side impulse will respond linearly to the message signal frequency. The modulated signal's transmission bandwidth will match the frequency of the message.

Demodulation (Time and frequency domains)

Coherent Demodulation

At first, the components were connected as shown in figure 40. And the function generator is set to: sine, V_{ss} = 4V and f_m = 2 kHz.

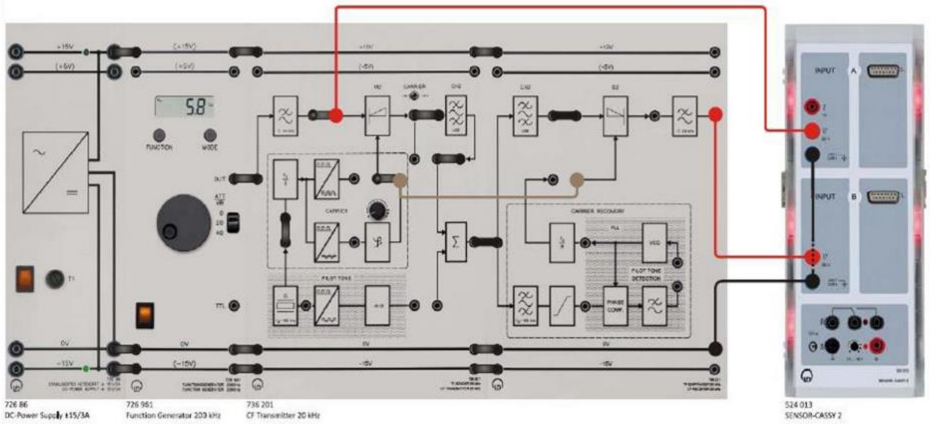

Figure 40: SSB-SC coherent demodulation connection

The phase controller (φ) is to be set to the leftmost position (Minimum value = 0°). The s(t) signal should be directly fed into the demodulator, and no filter is to be employed during its transmission. A sinusoidal carrier signal is to be introduced into the auxiliary carrier input of the demodulator using a wire.

In order to recover the carrier wave that was suppressed during modulation, the procedure of feeding a sinusoidal carrier signal into the demodulator's auxiliary carrier input is carried out in SSB-SC coherent demodulation. The modulated signal is then multiplied by this newly created carrier wave to produce a product signal that solely includes the original message signal. The demodulator can separate the message signal from the product signal by modifying the phase controller (φ) to coincide with the phase of the regenerated carrier wave. Because the phase of the regenerated carrier wave is synced with the original carrier wave and enables precise extraction of the message signal, this method is known as coherent demodulation.

Time Domine:

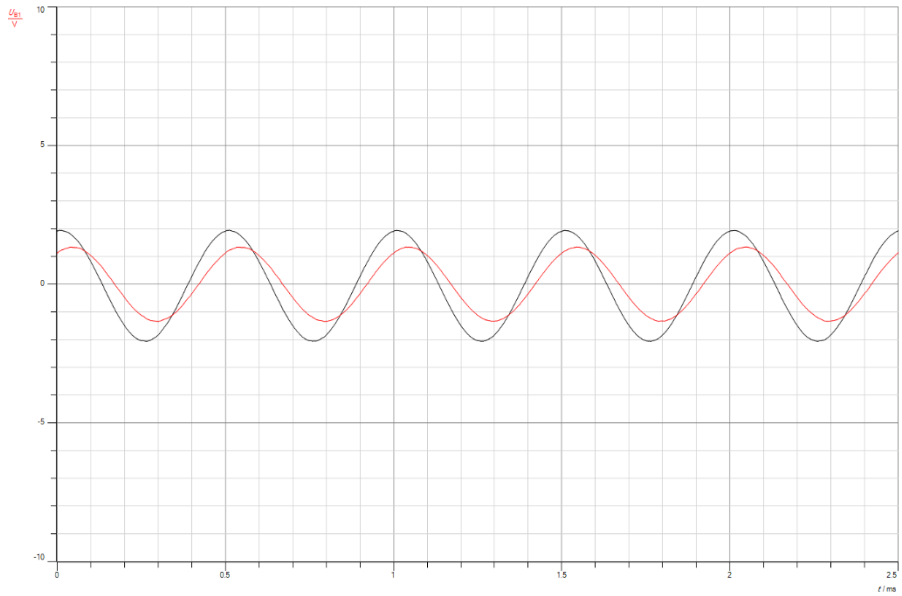

Figure 41: m (t) and s(t) in time domain

Frequency Domain:

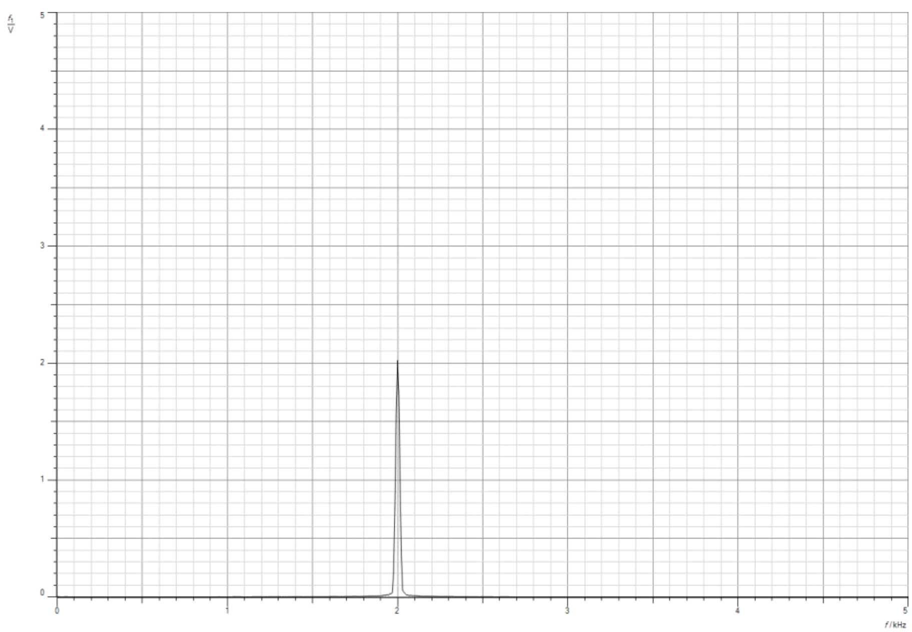

Figure 42: spectrum of the coherent demodulated signal

As shown in the previous picture, it seen the original massage Signal after the demodulation process.

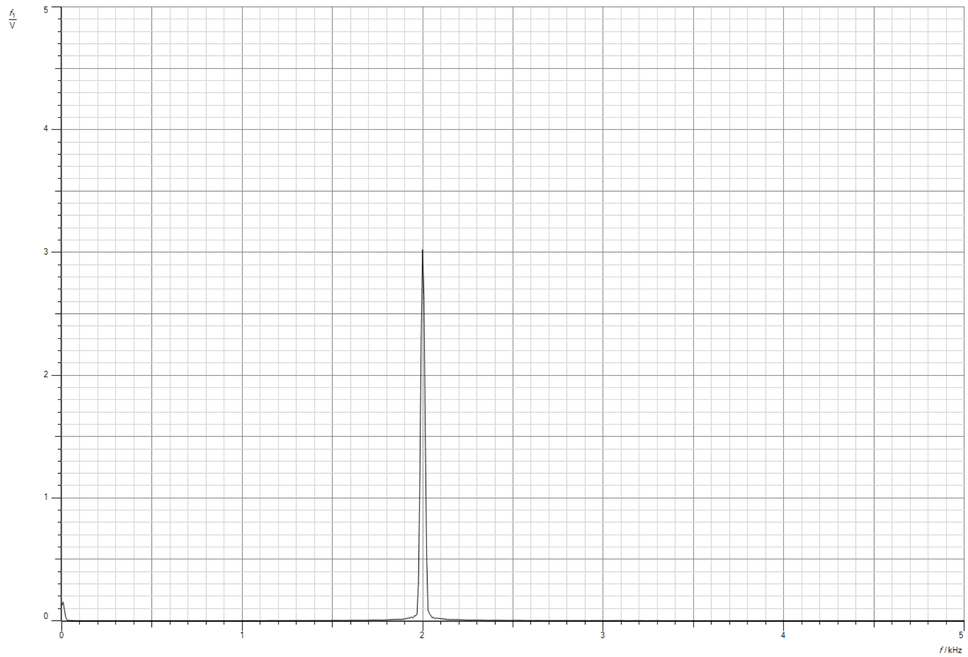

Figure 43: spectrum of the coherent message signal

In SSB-SC demodulation, the receiver output filter is used to eliminate undesired frequency components from the demodulated signal and to improve the recovered message signal's signal-to-noise ratio (SNR). Without it, the demodulated signal would include both upper and lower sidebands as well as noise and other undesired signals, which might make the message signal less clear.

The carrier wave at f_c + φ and the message signal at $2f_c$ - φ are the two frequency components that make up the demodulated signal mathematically. A lowpass filter is used to filter out the carrier wave component, leaving only the message signal, in order to extract the message signal. To prevent any attenuation of the message signal, the cutoff frequency of the filter should be set to a value only a little bit higher than the maximum frequency of the message signal. The original message signal can then be recovered by amplification and further processing of this filtered signal.

In order to eliminate undesired frequency components and improve the Signal-to-Noise Ratio (SNR) of the recovered message signal, the receiver output filter is essential in SSB-SC coherent demodulation.

Non-Coherent Demodulation

Time Domine:

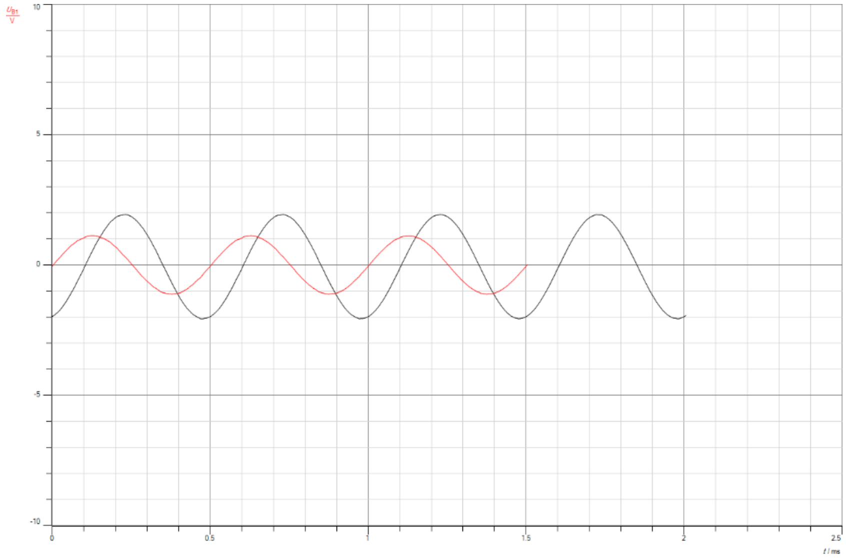

Figure 44: Noncoherent Demodulation Signal

It had returned to the original massage Signal following the Demodulation procedure, as seen in the preceding image. Notice the distortion that results from the message signal's Hilbert transform showing up at the output.

The output of the demodulator changes in amplitude and phase, which leads to distortion of the recovered message signal when the carrier phase from the phase shifter (φ) is altered. The non-coherence between the carriers utilized at the modulator and the demodulator is the cause of this distortion.

The output of the demodulator will lose amplitude and, in certain cases, even disappear entirely as the phase difference between the two carriers grows. This is because partial demodulation results from the non-coherent carrier's different phase relationship from the original carrier employed at the modulator.

When there is a 180-degree (pi radians) phase mismatch between the carrier signal at the modulator and the carrier signal at the demodulator, the output entirely disappears.

Phase Locked Loop (PLL) Coherent Demodulation

Using the Phase Locked Loop (PLL) is another method of coherent demodulation. This loop, which is located at the receiver, takes a reduced carrier signal and recreates a complete carrier signal that may be utilized for demodulation.

At first, the components were connected as shown in figure 45. And the function generator is set to: sine, v_{ss} = 4V and f_m = 2 kHz.

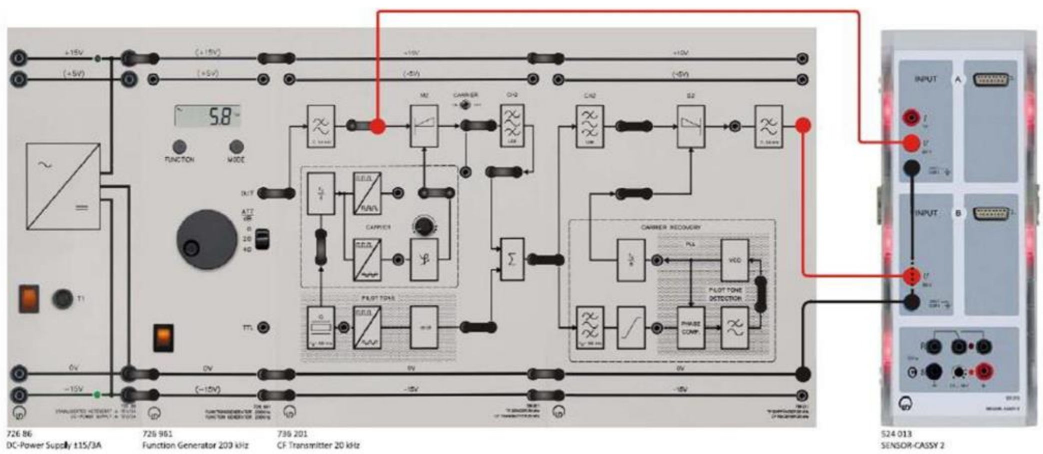

Figure 45: SSB-SC PLL demodulation connection

Time Domine:

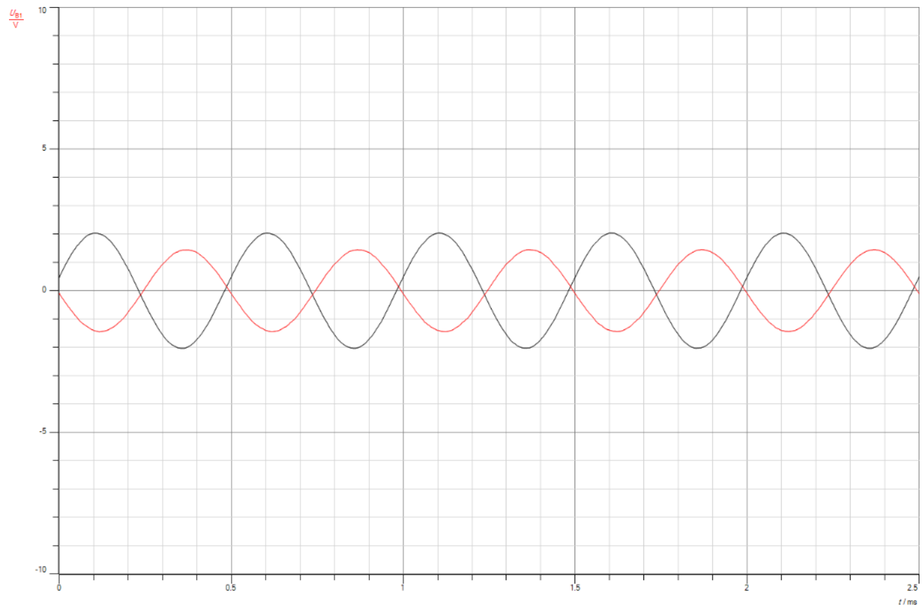

Figure 46: m(t) and demodulated signal in time domain PLL Coherent Demodulation

As shown, the original message has been recovered, but with a phase shift.

Frequency Domain:

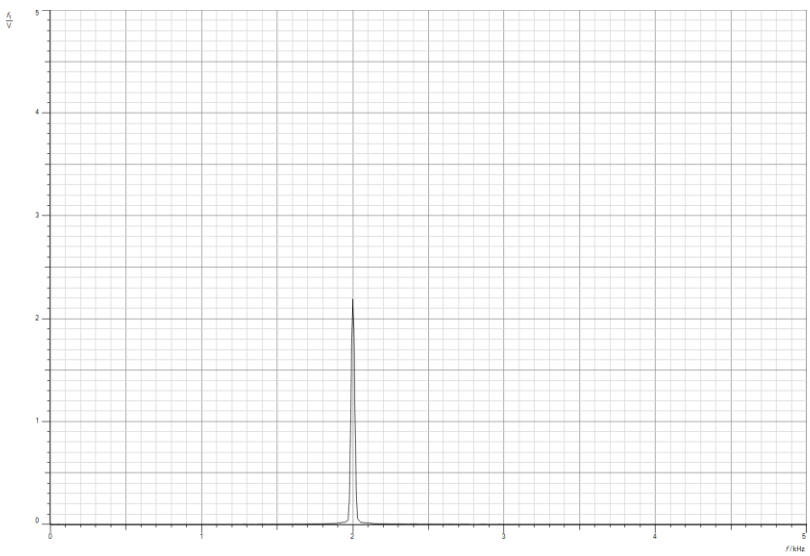

Figure 47: spectrum of the PLL demodulated signal

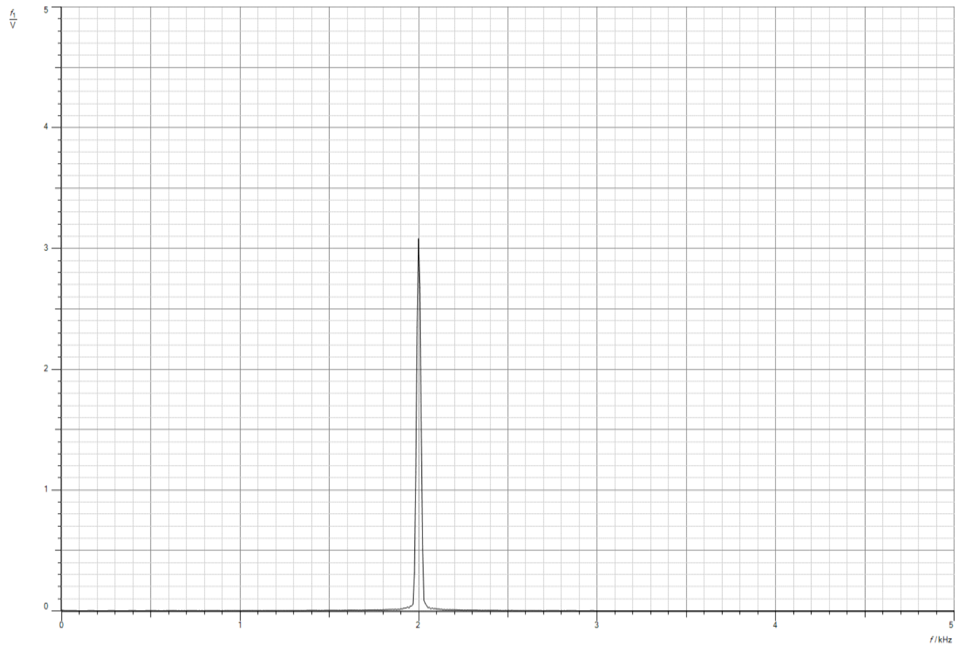

Figure 48: spectrum of the message signal

Conclusion

At the end of the experiment, we learned a new amplitude modulation technique which is Double Side Band Suppressed Carrier (DSB-SC), and Single Side Band Suppressed carrier (SSB-SC). Also, we understood three demodulation strategies (coherent, non-coherent, and Phase Locked Loop (PLL) coherent). We observed that DSBSC modulation is simpler to implement but wastes half of the power on the carrier signal, while SSBSC modulation is more efficient but requires more complex circuits.

In addition to that, we learned the differences between the three demodulation techniques, it was found that each one used the same idea of multiplying the carrier with the modulated signal. They are not the same as the views on power and efficiency. Given that the PLL coherent technique's transmitted power is much lower than that of the traditional coherent method while keeping in mind that the receiver must ensure that the recovered carrier has the same phase as the sent this approach may be regarded as being the most effective.

Additionally, the two modulation approaches' two domains (time and spectrum) have been studied and understood the experiment's findings help us comprehend the impact of altering a few message characteristics in order to determine how they impact the modulation and demodulation processes. The experiment was a success, and the outcomes confirmed the predictions of the theory.

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