جامعة بيرزيت

BIRZEIT UNIVERSITY

Faculty of Engineering & Technology

Electrical and Computer Engineering Department

Communications Laboratory

Report #3:

Experiment No 11. Frequency and Phase Shift Keying

Prepared by:

Arwa Doha 1190324

Partners:

Hamza Awashra 1201619

Saleh Zhour 1201941

Instructor: Dr.Ashraf Al-Rimwi

Assistant: Mohammad Al-Battat

Section: 6

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Abstract

The aim of this experiment is to understand digital communication systems, specifically frequency and phase shift keying. We experiment with two types of keying known as the soft and hard keying. Moreover, we show the modulation and demodulation of signals in both the frequency domain and time domain and discuss the results in comparison with the theoretical part. We discuss the importance of various mathematical equations such as the probability of error and the energy of different signals that are used in frequency and phase shift keying.

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Theory

2.1 Frequency and Shift Keying Modulation

In the digital communication, the initial stage involves an analog to digital converter (ADC), a multifaceted component that encompasses a sampler, a quantizer, and an encoder. Subsequent to this process, line encoding ensues, furnishing the modulator with its requisite input. The modulator, in turn functions to yield a binary output, comprising the values of zero and one, which are correspondingly manifested as S1(t) and S2(t). A visual representation of this sequential arrangement can be found in the accompanying block diagram, which meticulously depicts the architecture of a digital communication system.[1].

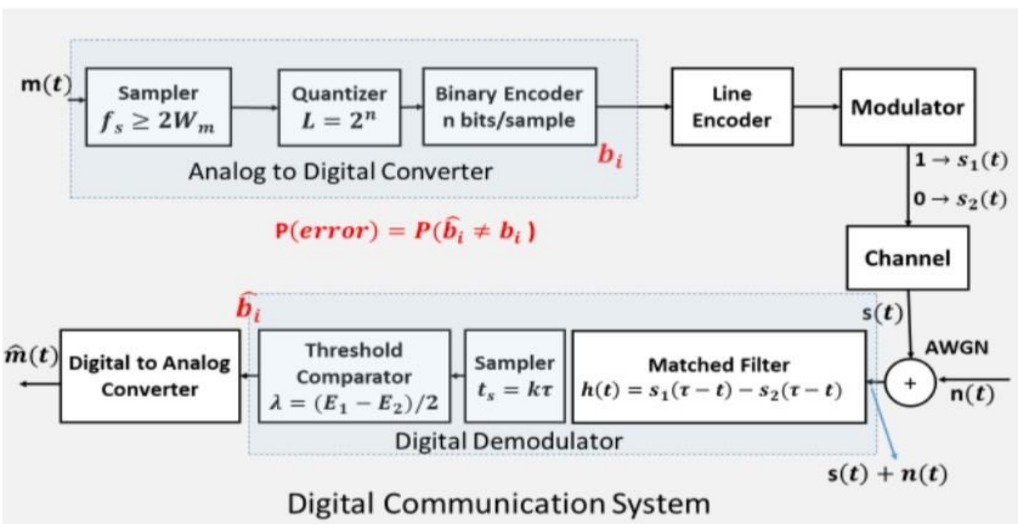

Figure 1: Digital Communication System [1]

Frequency shift keying is a digital modulation technique where the frequency of the modulated signal changes with respect to the digital signal(message signal). When the digital signal is 1, the frequency of the modulated signal is very high. In contrast, when the digital signal is 0, the frequency of the modulated signal is lower. In phase shift keying, the modulated signal's phase changes when there is a change in the value of the digital signal. When the digital signal changes from 0 to 1 or from 1 to 0, we see a change in the phase while the frequency and amplitude remain constant. In the figure below, we see the modulated carrier signal changes its frequency in accordance with the message signal.[2].

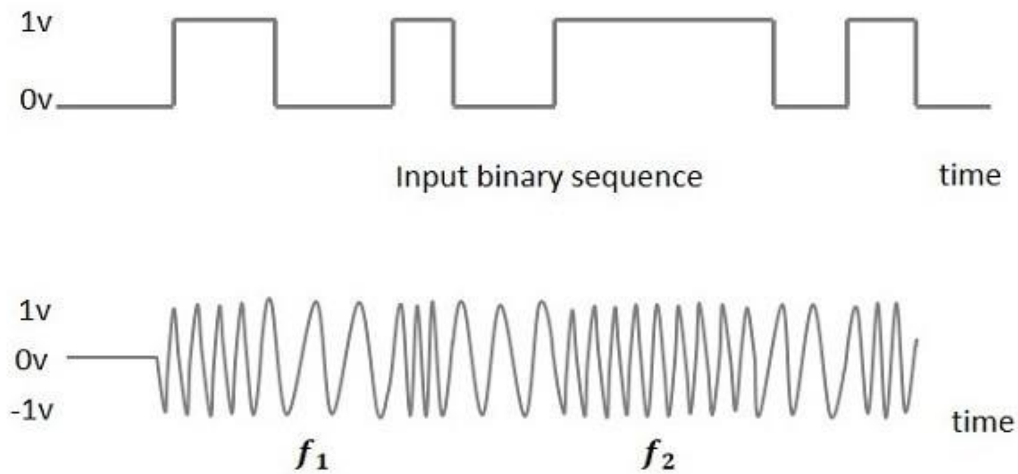

Figure 2: Frequency Shift Keying Modulated output wave [3]

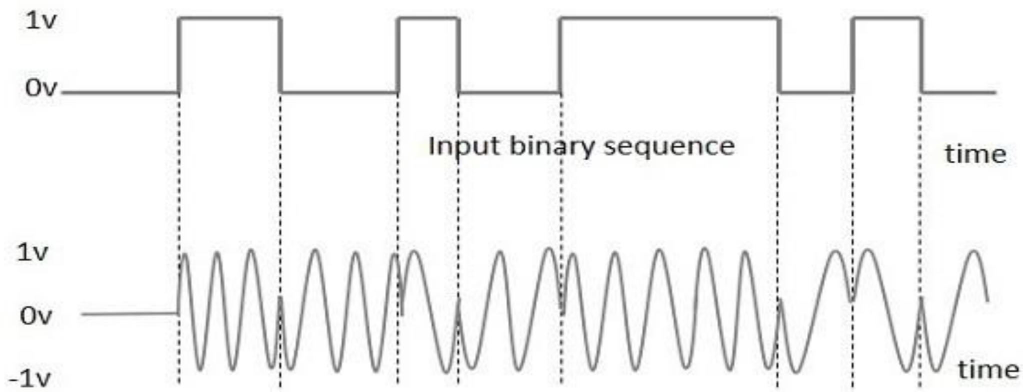

Figure 3: Phase Shift Keying Modulated output wave [2]

There are two types of shift keying in amplitude shift keying, phase shift keying and frequency shift keying, which are hard keying and soft keying. In hard keying the response time is very fast. In regards to frequency and phase shift keying, when the digital signal changes its value from 0 to 1, the change in frequency or phase happens quickly unlike in soft keying, where the response time is small.[3].

2.2 Frequency and Phase Shift Keying Demodulation

The optimum binary receiver can be done in two ways, either by using a matched filter or a correlator, which is a multiplier followed by an integrator. After that we use a threshold comparator to set the threshold. The final block is the digital to analog convertor. The bottom half of Figure 1 shows the receiver side in digital communications[1].

Equation 1 below, calculates the threshold by calculating the energy of the two signals, subtracting them, and dividing by two. Equation 2 is calculating probability of error using the Q function due to the noise caused in the transmission. S1(t) and S2(t) are two signals and No is the thermal noise. Equation 3 is the Energy calculated for both FSK and PSK. Here τ is the bit duration[1].

Equation 1) Threshold = (E1 - E2) / 2

Equation 2) Probability of Error =

$$P_b^* = Q\left(\sqrt{\frac{\int_0^\tau (s_1(t) - s_2(t))^2 dt}{2N_0}}\right)$$

Equation 3) Energy= $\int$ S(t)^2 = (A^2*τ) / 2

Equation 4) Bit Rate Rb = 1/τ

Equation 5) Bandwidth for PSK= 2Rb

Equation 6) Bandwidth for FSK = 2Rb+2ΔF

Using the threshold value, we can compare the value of the sampler or integrator output. If the value is below the threshold then zero is sent to the DAC, and if the value is greater than threshold, then one is sent to the DAC.

Procedure and Data Analysis

3.1 Frequency shift keying Modulation

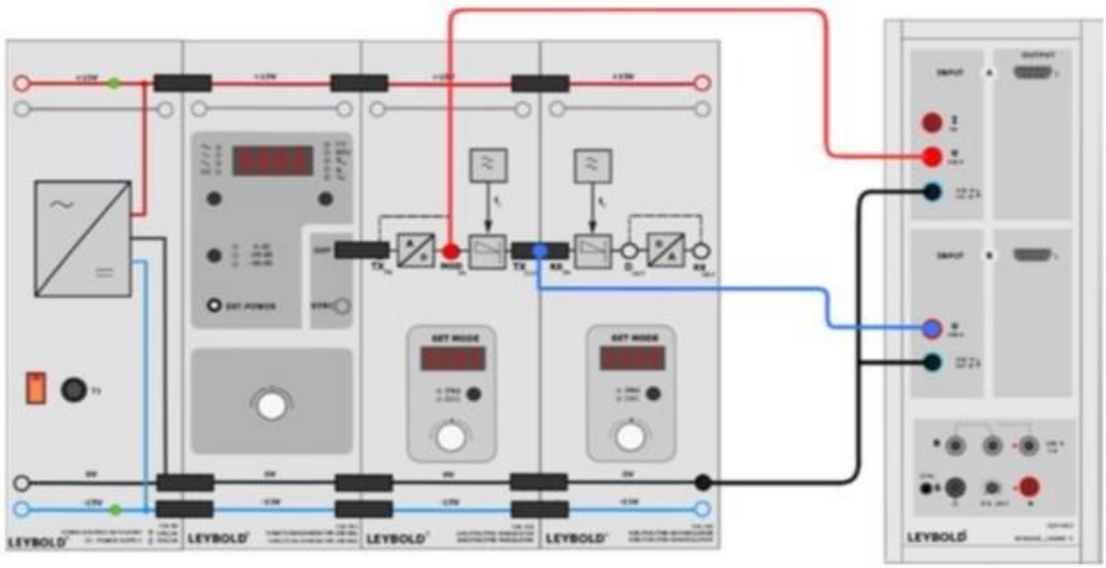

Figure 4: Frequency Shift Keying Setup [4]

First we set the function generator to Square wave, Freq= 1000 Hz, Vss= 10V, duty-cycle= 50%. Then we set the modulator mode to DIG(digital). Select Frequency shift keying – Hard keying (F_1).

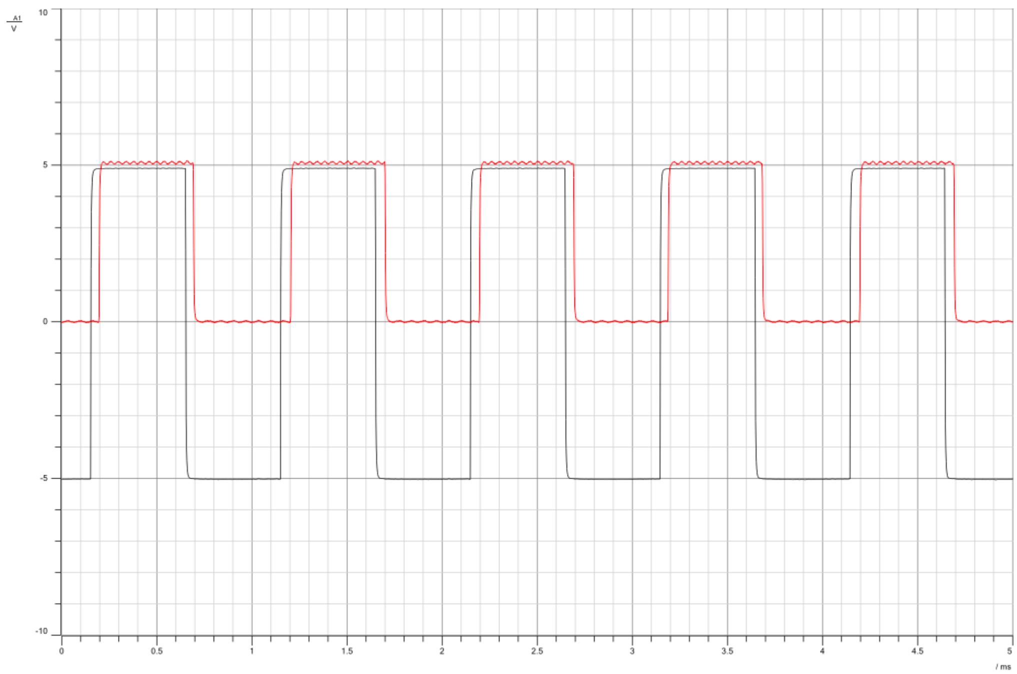

Figure 5: Modulating signal and Unipolar square wave signal(Hard Keying)

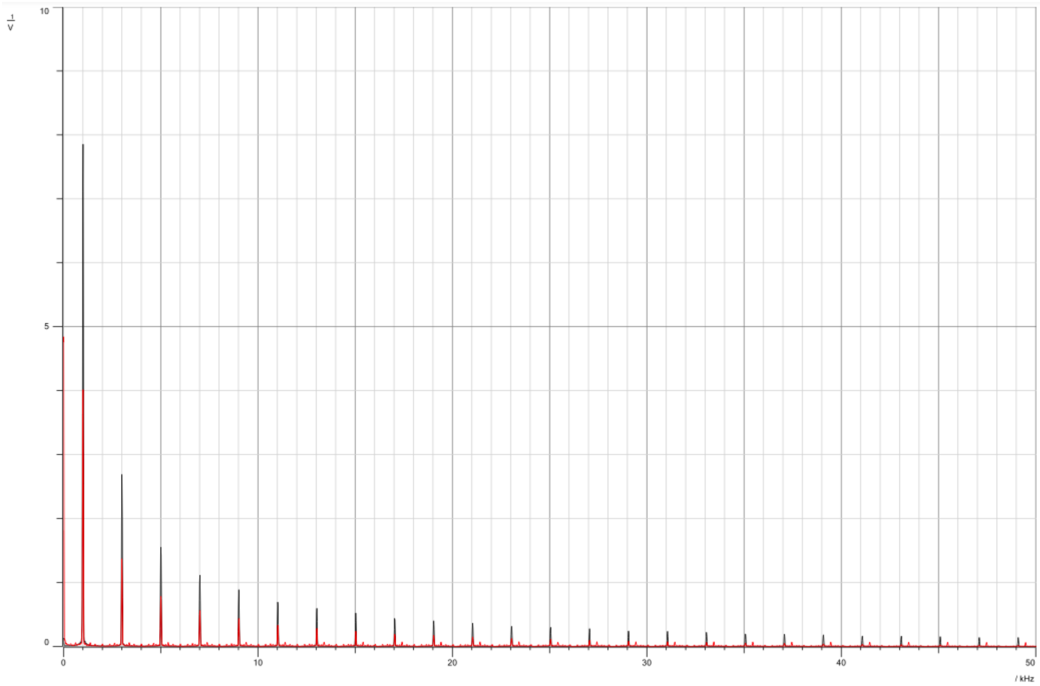

Figure 6: Modulating signal and Unipolar square wave signal in Frequency Domain

As can be seen in the figure above, we first set up an analog signal that has an amplitude of 5. This signal is then converted to digital using th analog to digital block in the set. We see now the values are either 0 or 1, this is done using the lin encoding unipolar NRZ.

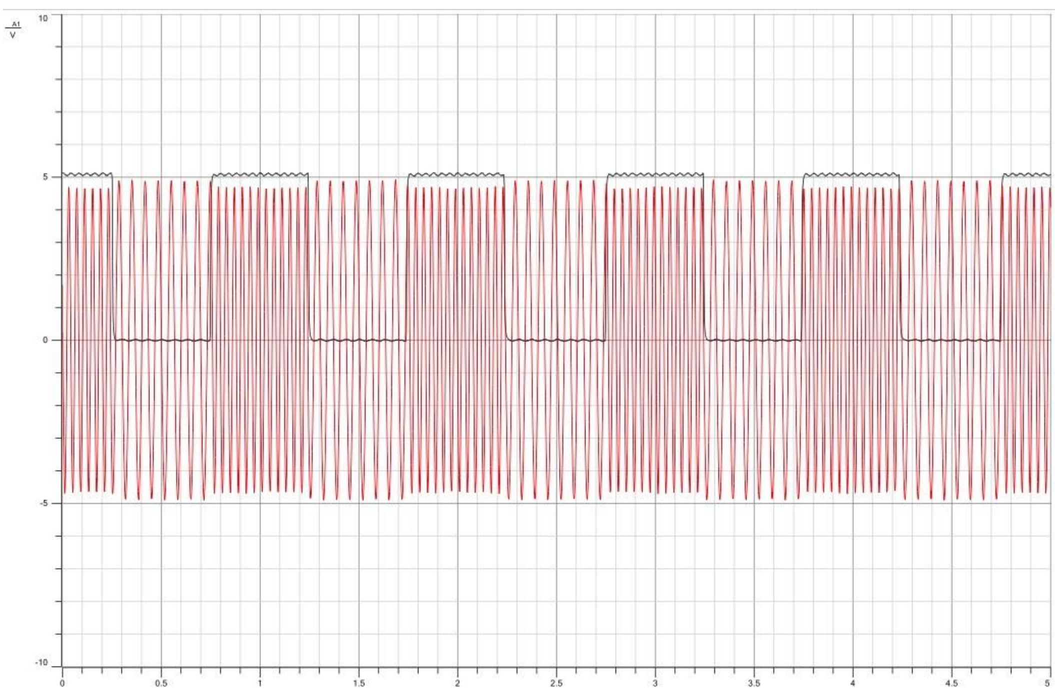

Figure 7: Unipolar square wave signal and Modulated Signal

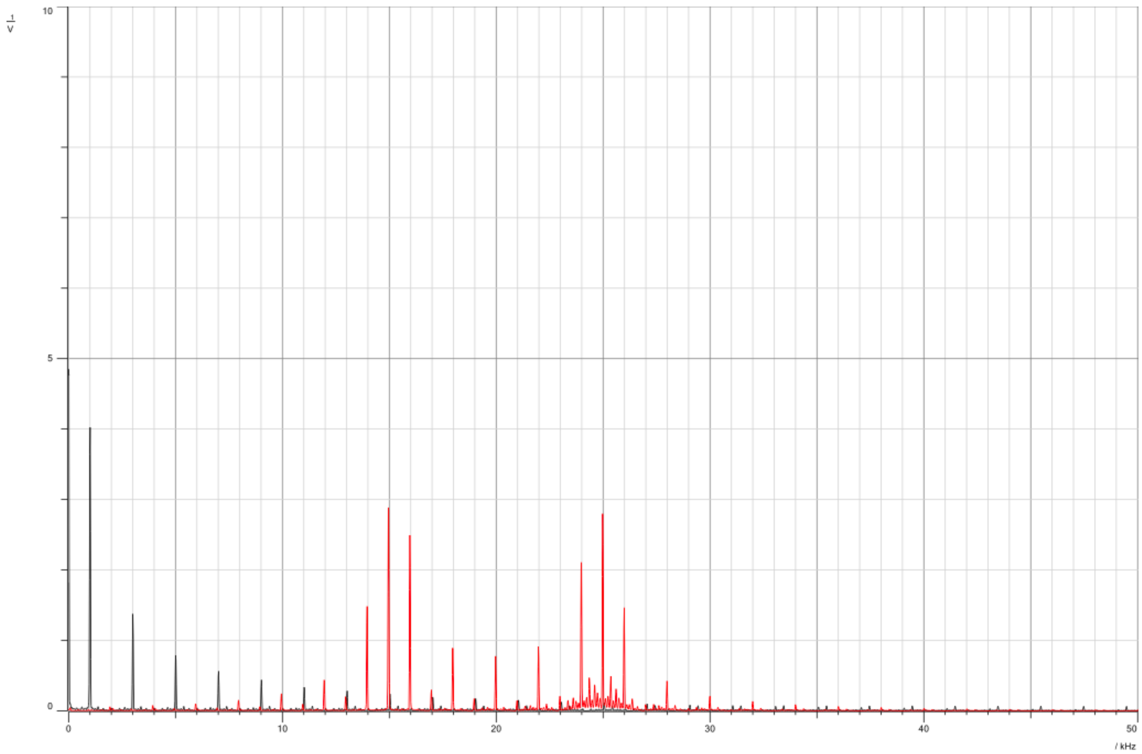

Figure 8: Unipolar square wave signal and Modulated Signal in Frequency Domain

As in Figure 7, the frequency is greater when the digital signal is 1, and when the digital signal is 0, the frequency is lower. In figure 2 red impulses represent the 2 envelope sinc shaped functions of the modulated FSK signal. Here the frequency of the carrier signal is 20khz, and the centers of each envelope sinc shaped signals are at 15khz and 25khz, which represent fc - (delta F), and fc+(delta F) respectively. Thus we can conclude that delta F is equal to 5khz.

In Figure 7, we can see the change in the frequency of the carrier signal as soon as the digital signal changed values. This change had a quick response time since we are dealing with hard keying. Now we select the frequency shift keying – soft keying (F_2) and see the difference in the response time.

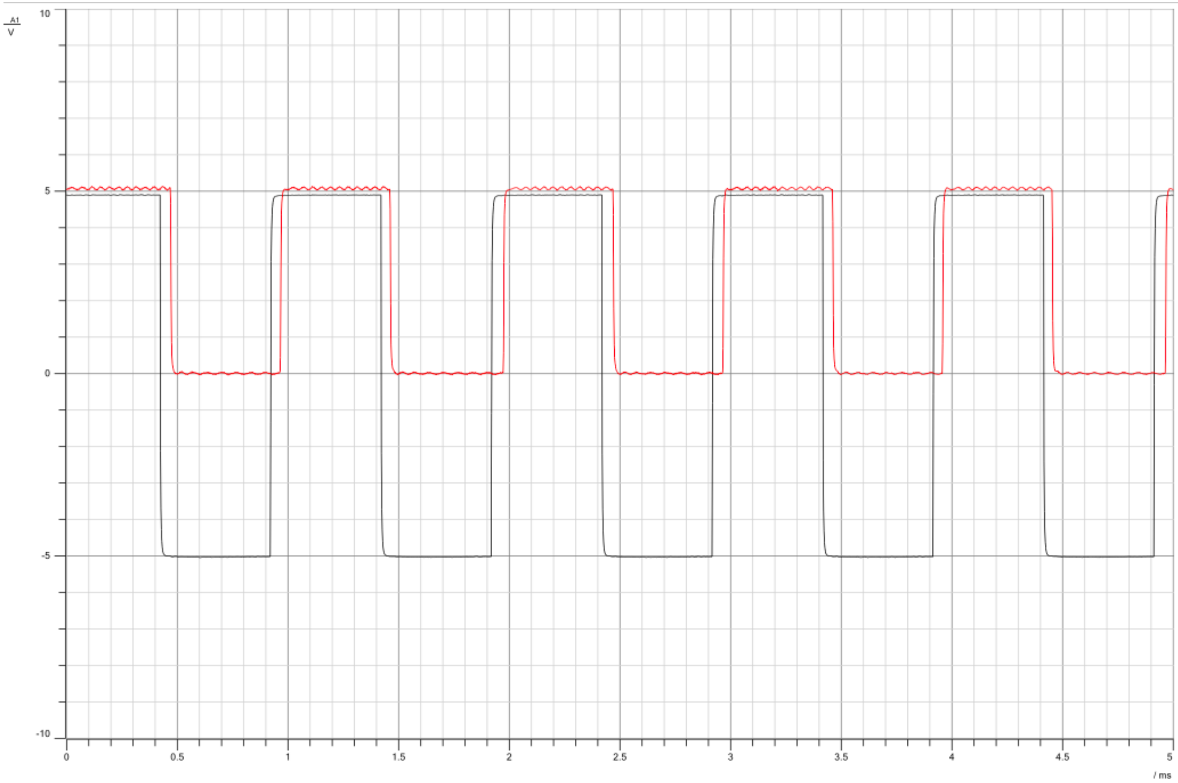

Figure 9: Modulating signal and Unipolar square wave signal(Soft Keying)

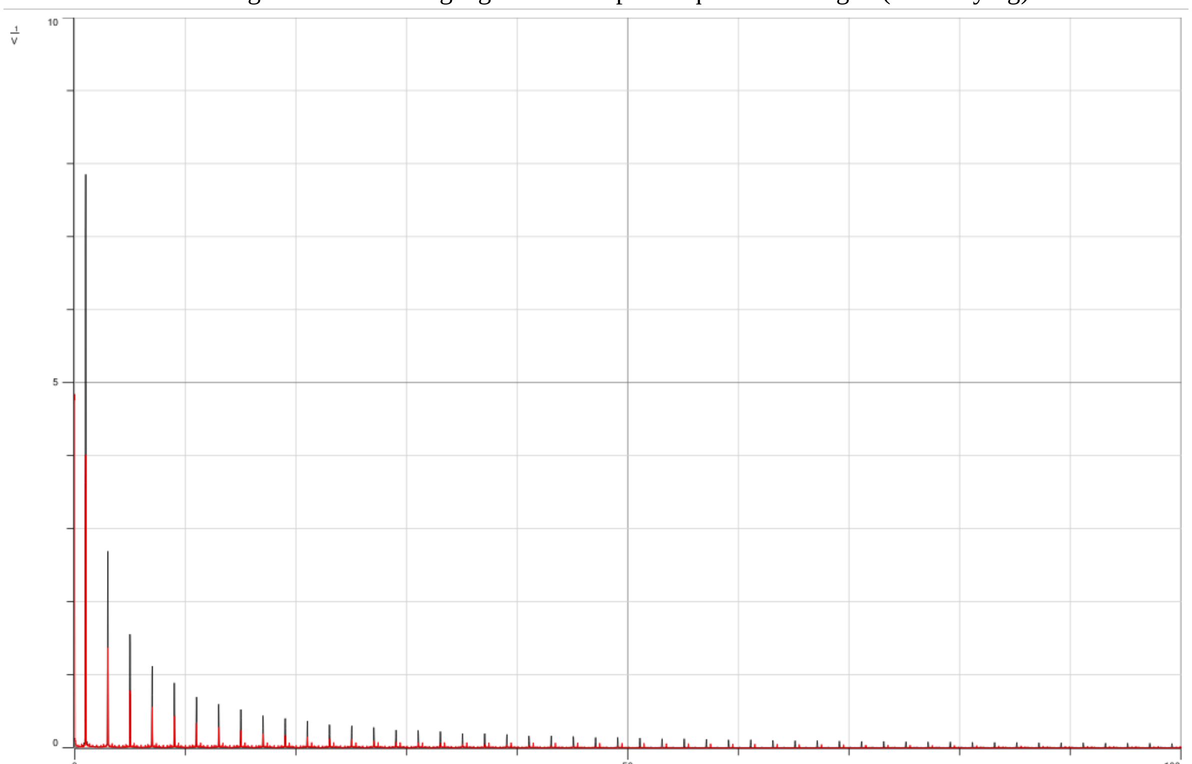

Figure 10: Modulating signal and Unipolar square wave signal in Frequency Domain(Soft Keying)

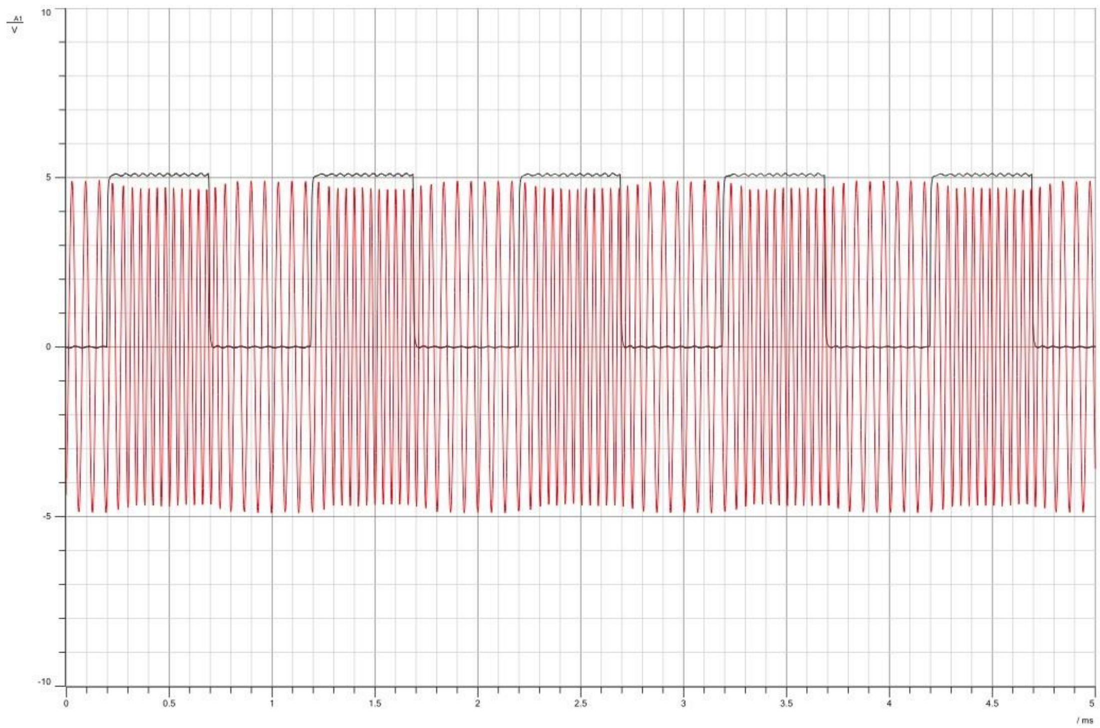

Figure 11: Unipolar square wave signal and Modulated Signal(Soft Keying)

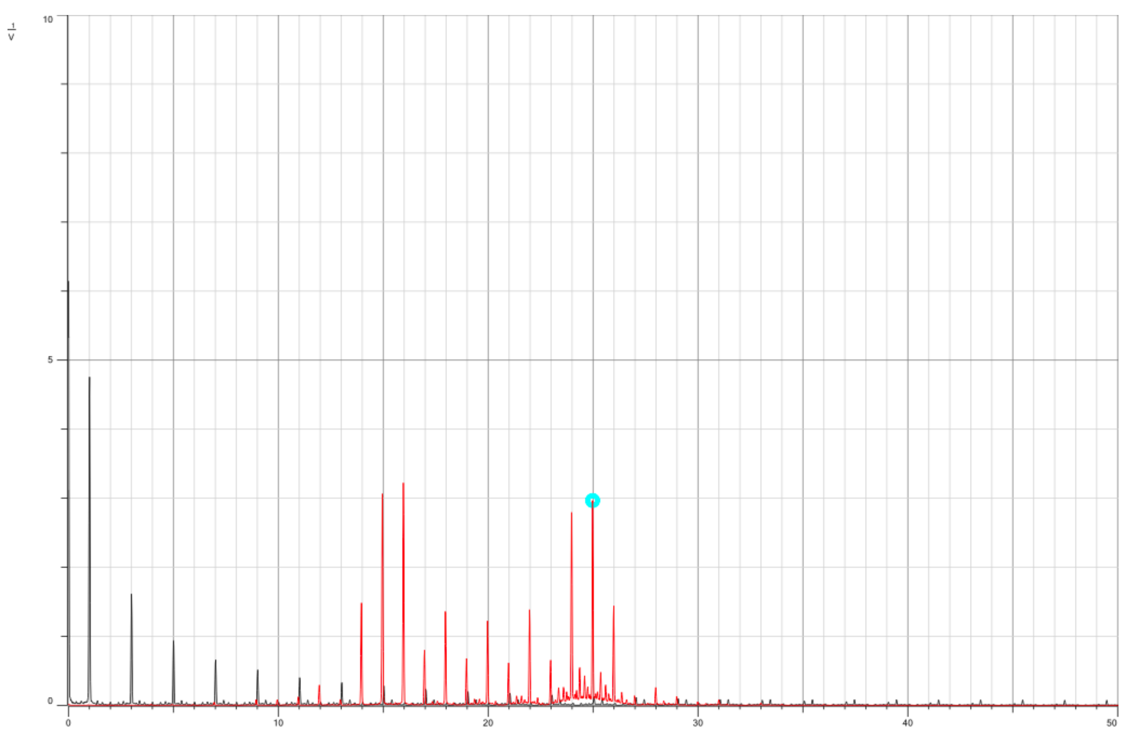

Figure 12: Unipolar square wave signal and Modulated Signal in Frequency Domain (Soft Keying)

Soft and Hard keying does not affect the signal in the frequency domain. It affects the response time, which can be seen in the time domain in both ASK and FSK.

Let's explore the impact of altering the message signal's amplitude. As outlined in the theory section, the DAC's output hinges on the threshold's determination. In this context, the upper threshold stands at 2.3, while the lower threshold rests at 1.67. Consequently, if the signal's Amplitude falls below 2.3, it transmits the value 0; surpassing 2.3 prompts a transmission of the value 1. For our specific kits, the 0 binary value corresponds to a frequency of 15kHz, while the 1 binary value aligns with 25kHz. In the diagram below, we've decreased the message signal's amplitude to 2v (Vss=4). Consequently, as the amplitude dips below the threshold, the impulse shifts to 15kHz instead of the anticipated 25kHz.

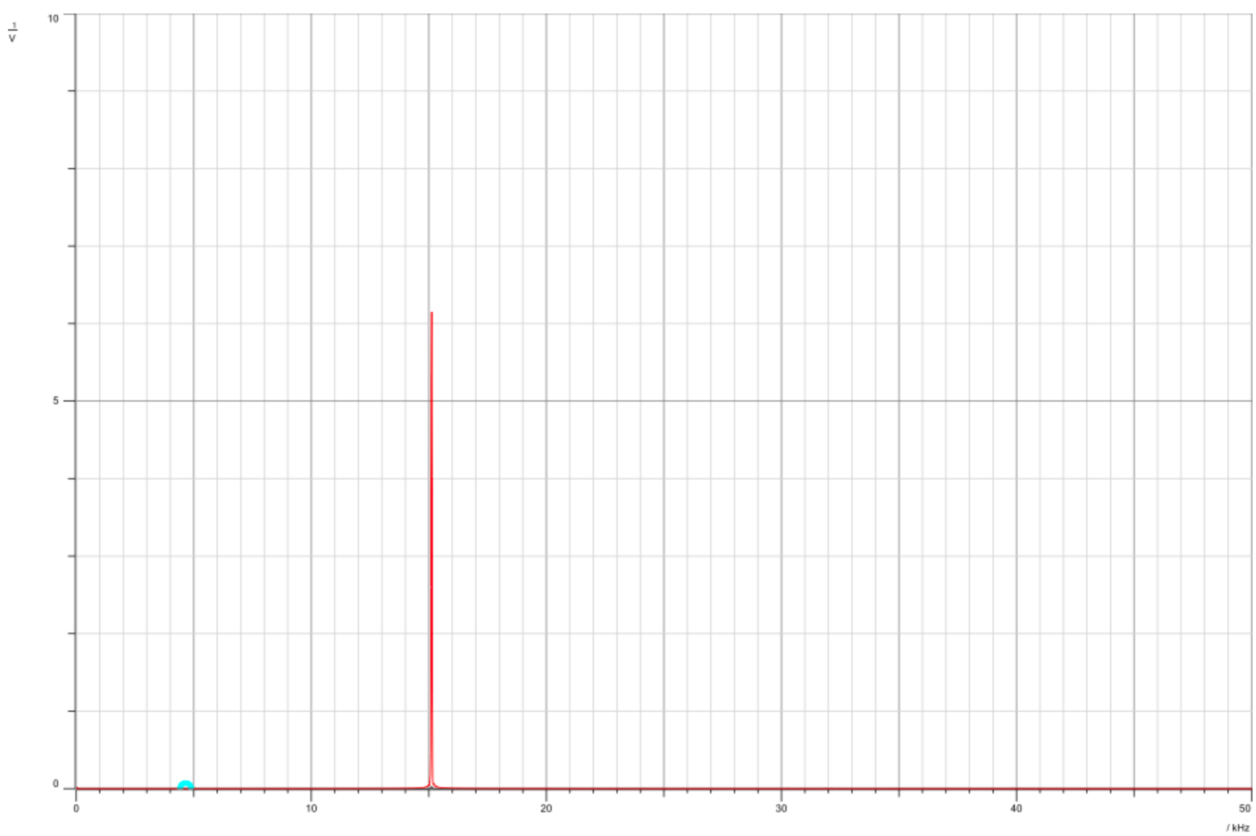

Figure 13: Signal sent at binary value 0, with frequency 15khz

Now we will study the effect of changing the frequency of the message signal. We set the function generator to the following: Square wave, Freq = 500 Hz, Vss = 10V, duty cycle = 50%.

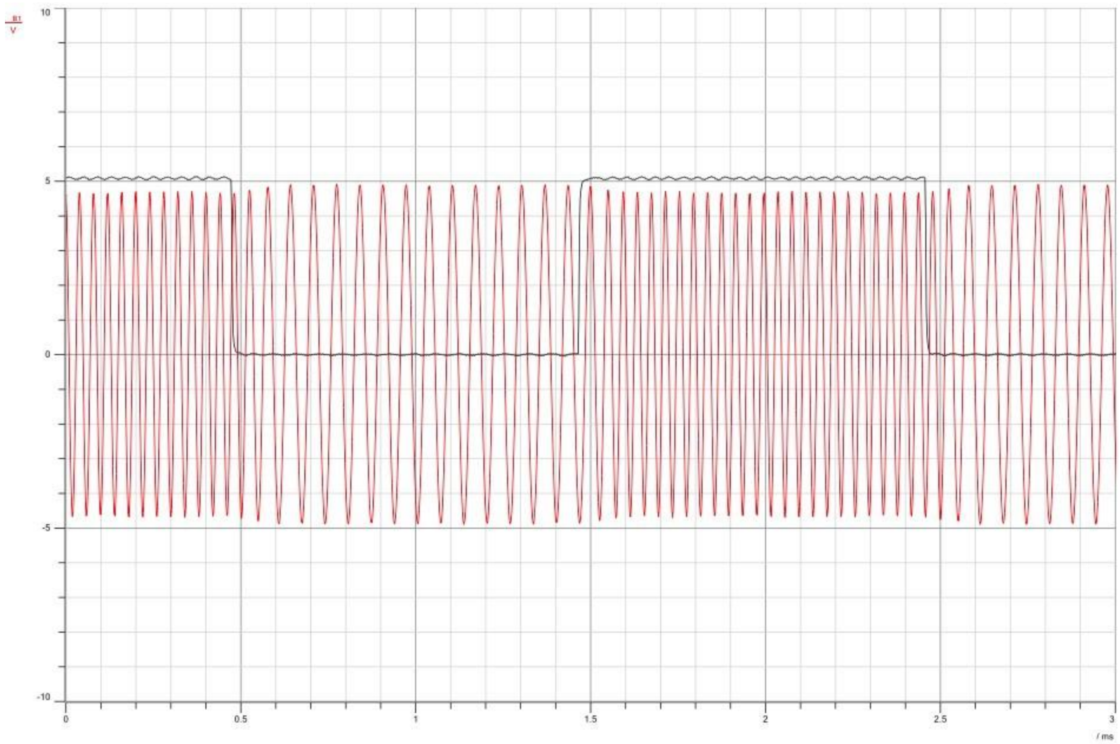

Figure 14: Unipolar signal and Frequency Shift Keying signal with fm=500hz

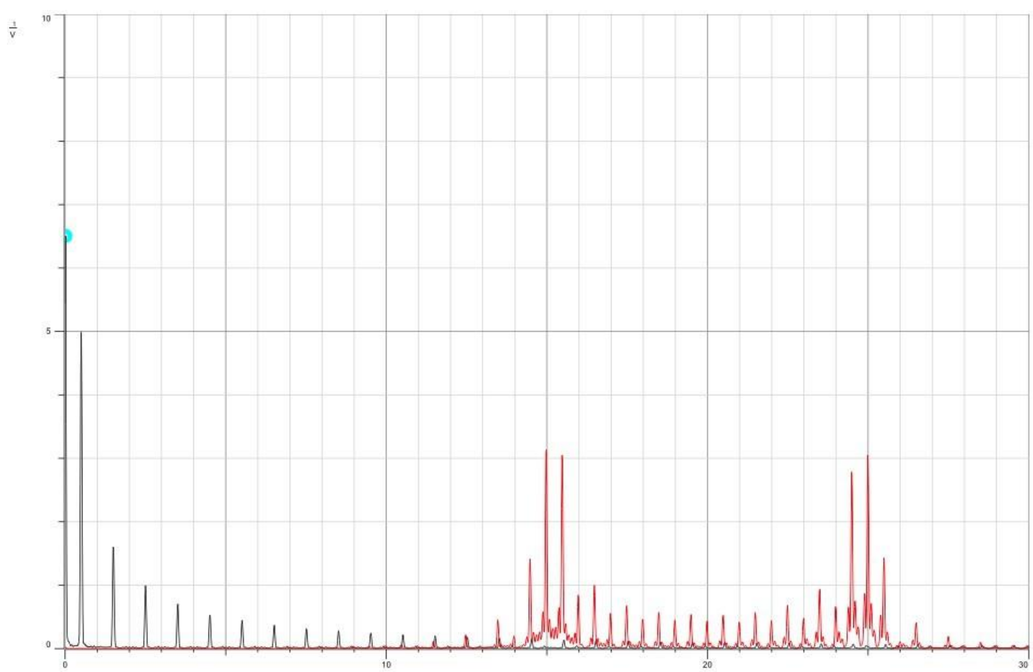

Figure 15: Unipolar signal and Frequency Shift Keying signal with fm=500 hz in Frequency Domain

The frequency domain illustrates the message signal's frequency at 500Hz. Notably, as we decrease the frequency from 1kHz to 500Hz, there's a discernible increase in the number of impulses concentrated around the centers of the enveloped sinc-shaped signals.

Let's explore the impact of adjusting the duty-cycle. When we set the duty-cycle to 10%, we observe in the frequency domain that the impulse-at the lower frequency gains more emphasis compared to the impulse at the higher frequency. However, with a duty-cycle of 50%, both centers receive equal emphasis, as depicted in the figures below.

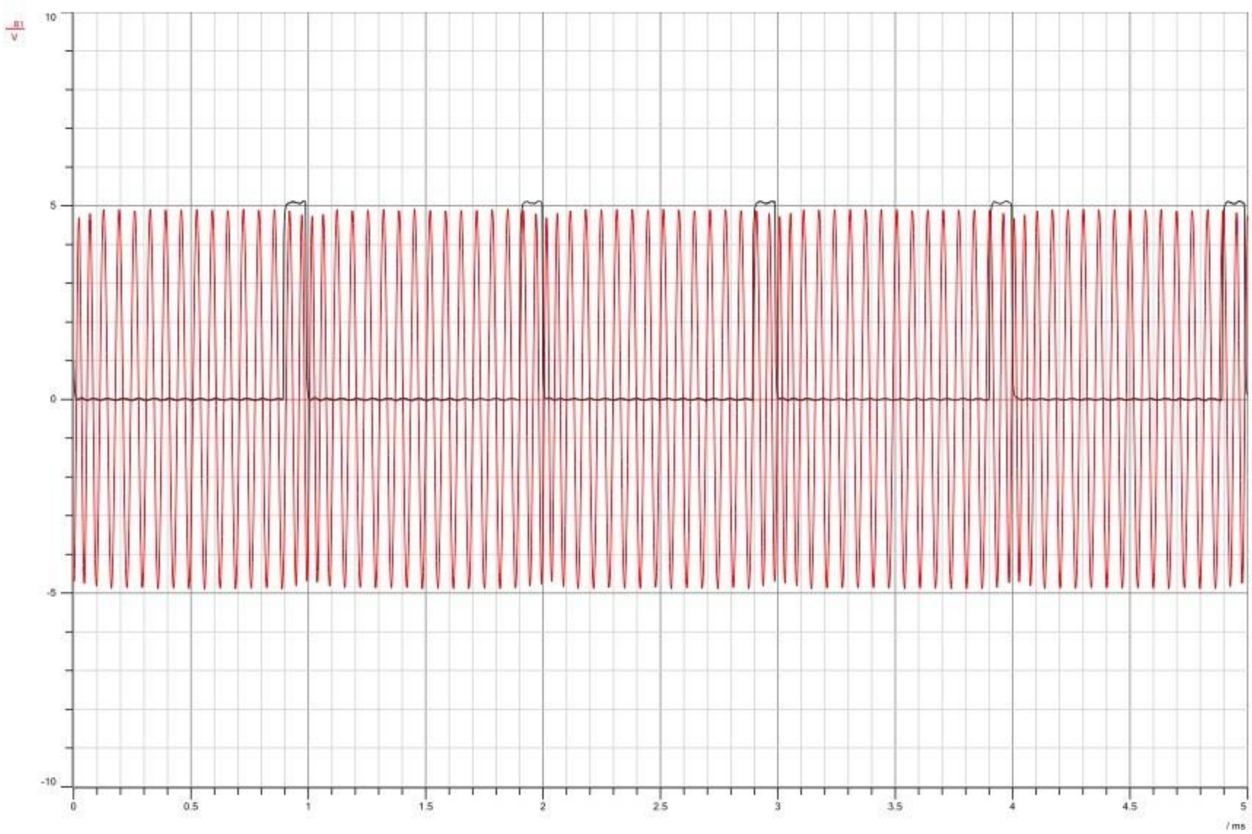

Figure 16: Signals with duty cycle 10%

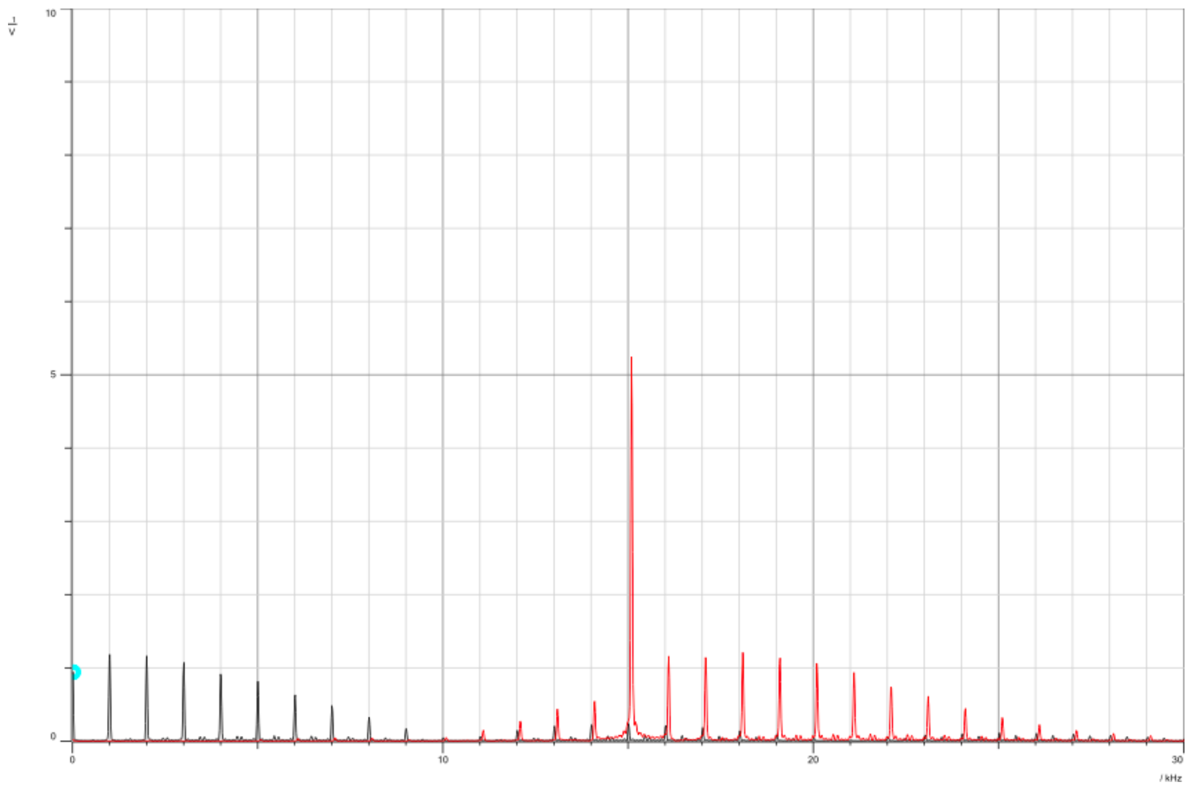

Figure 17: Signals with duty cycle 10% in Frequency Domain

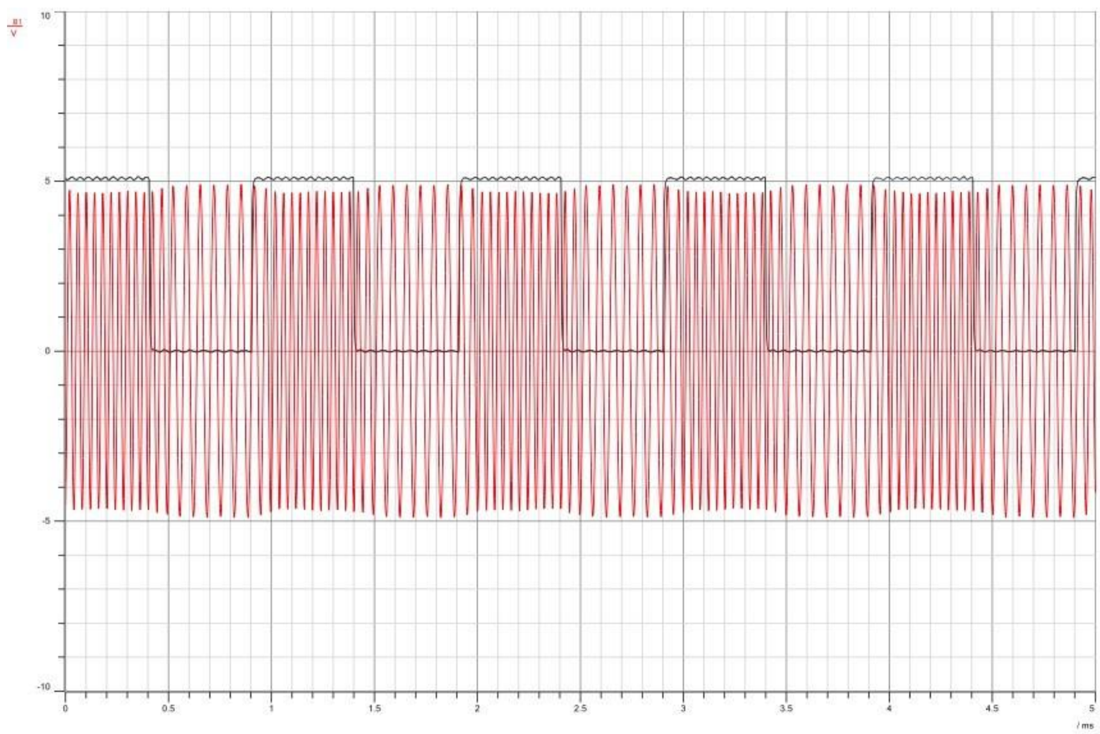

Figure 18: Signals with duty cycle 50%

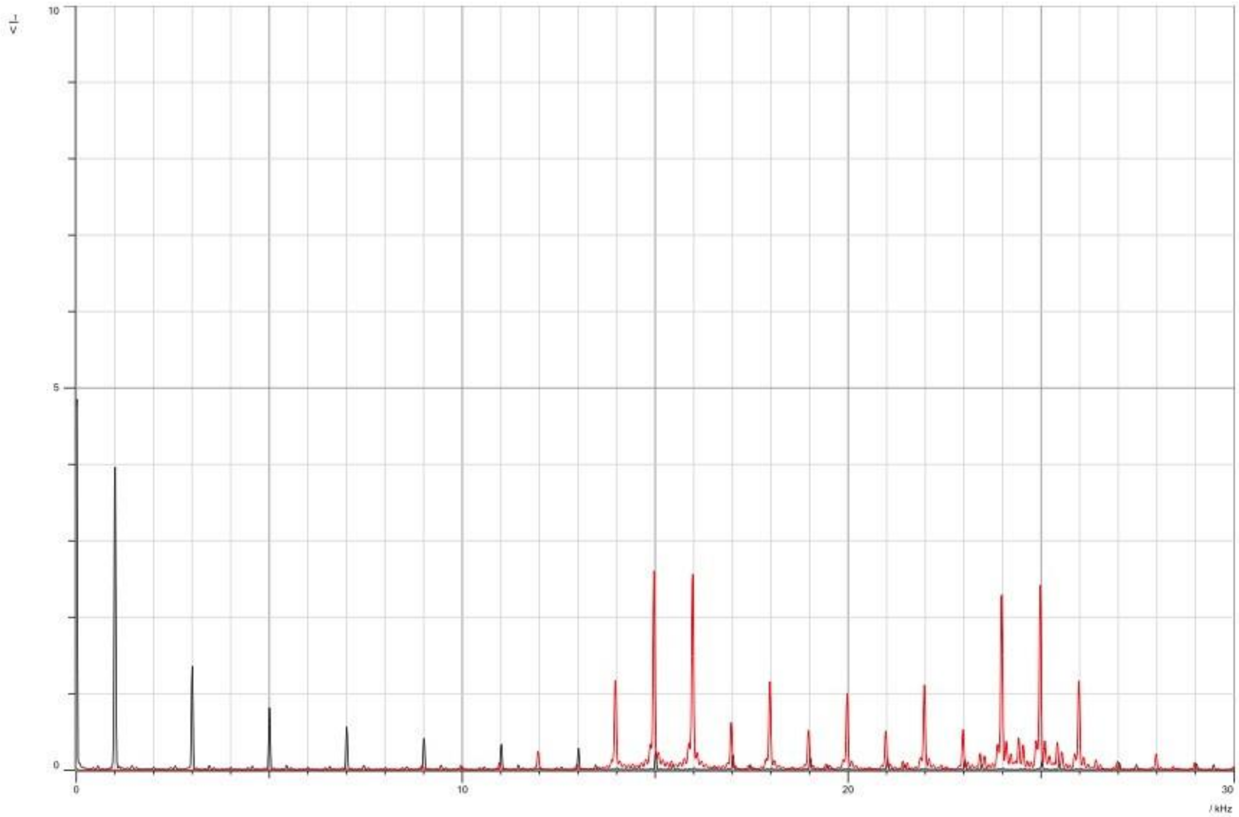

Figure 19: Signals with duty cycle 50% in frequency Domain

3.2 Frequency shift keying Demodulation

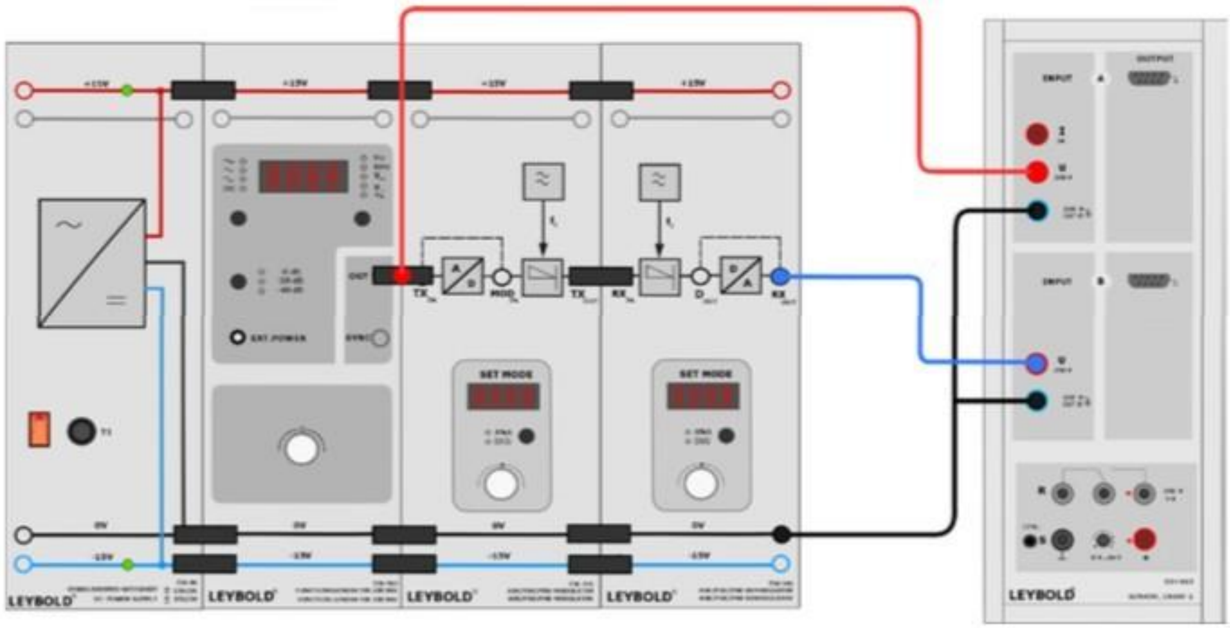

Figure 20: Frequency Shift Keying Demodulation Setup [4]

You've set the function generator with the following configurations: Square wave, Frequency= 1000 Hz, Vss= 10V, and a duty cycle of 50%. Additionally, you've selected the demodulator mode as Digital (DIG) and opted for demodulation type (F).

In the figures below, we can see the bipolar message signal with amplitude 5 and the demodulated signal. In the frequency domain, the demodulated signal has successfully retrieved the message signal with the same frequency. However, in the time domain figures, we can see that the 2 signals dont perfectly align with one another, there is a small shift. In theory, the demodulation process is ideal and retrieves the exact message signal in its exact form. However, in practical implementation it is difficult to have the two signals align perfectly on top of each other because there is always some kind of interference and noise. This imperfection can also be caused by filter characteristics as there is no ideal filter practically achieved.

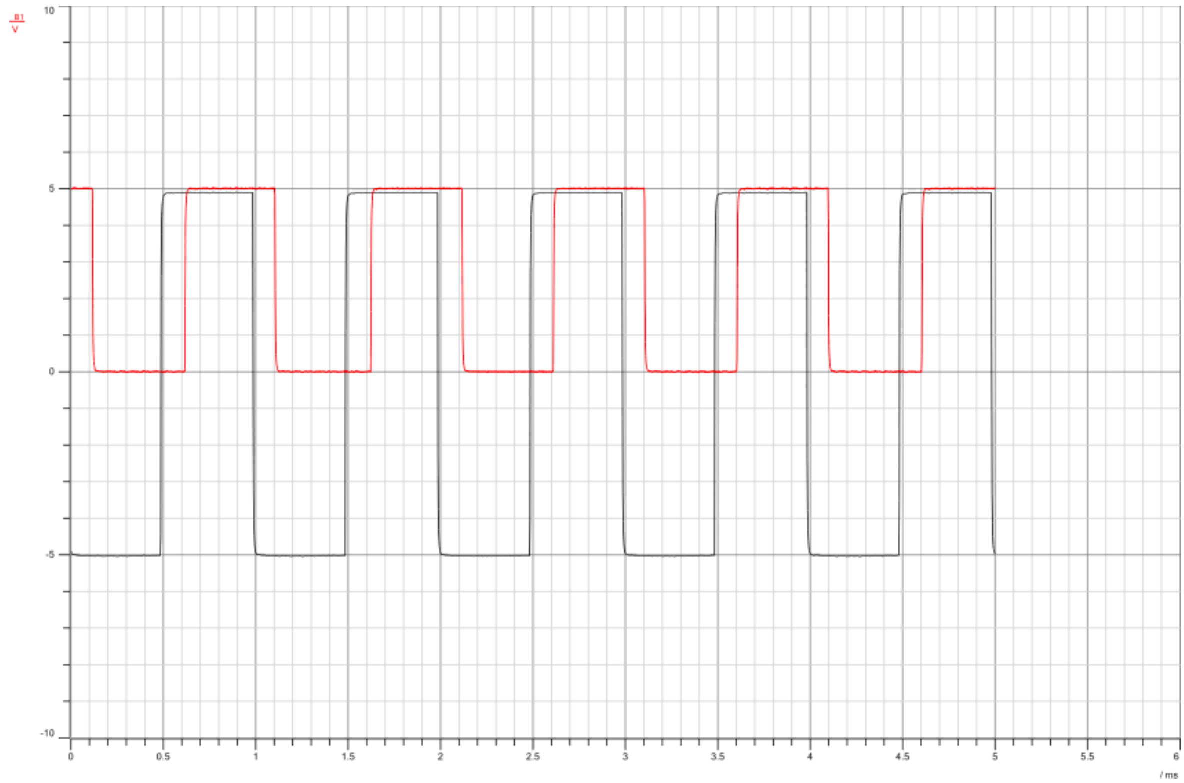

Figure 21: Bipolar message and demodulated signals in Time Domain (Hard keying)

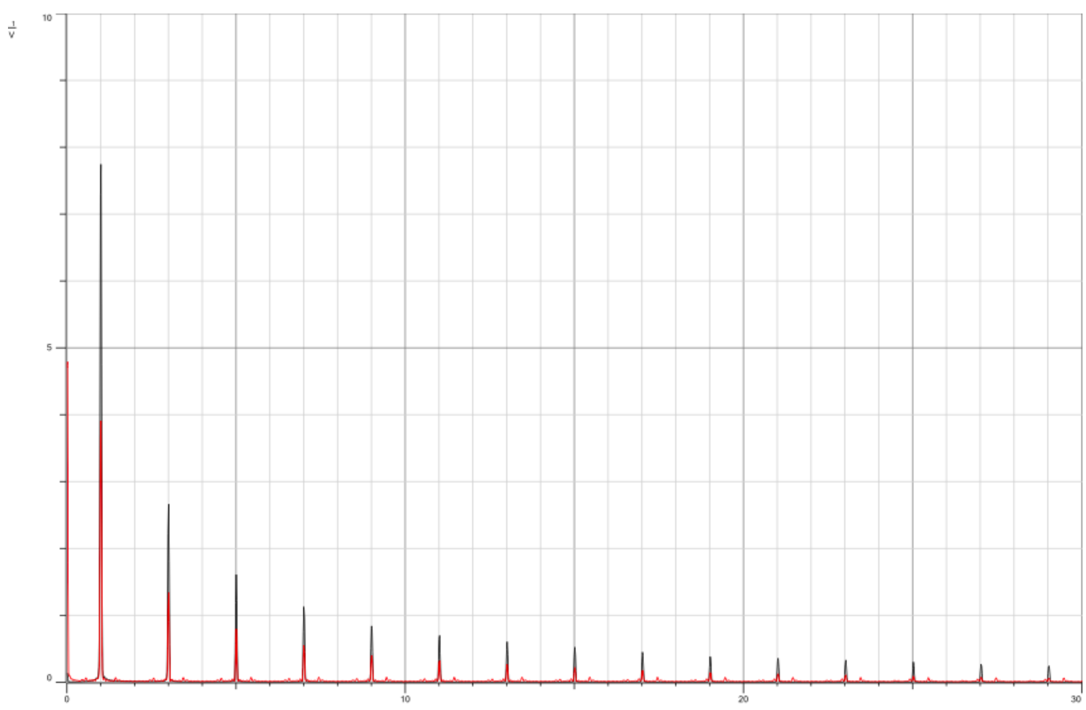

Figure 22: Bipolar message and demodulated signals in Frequency Domain (Hard keying)

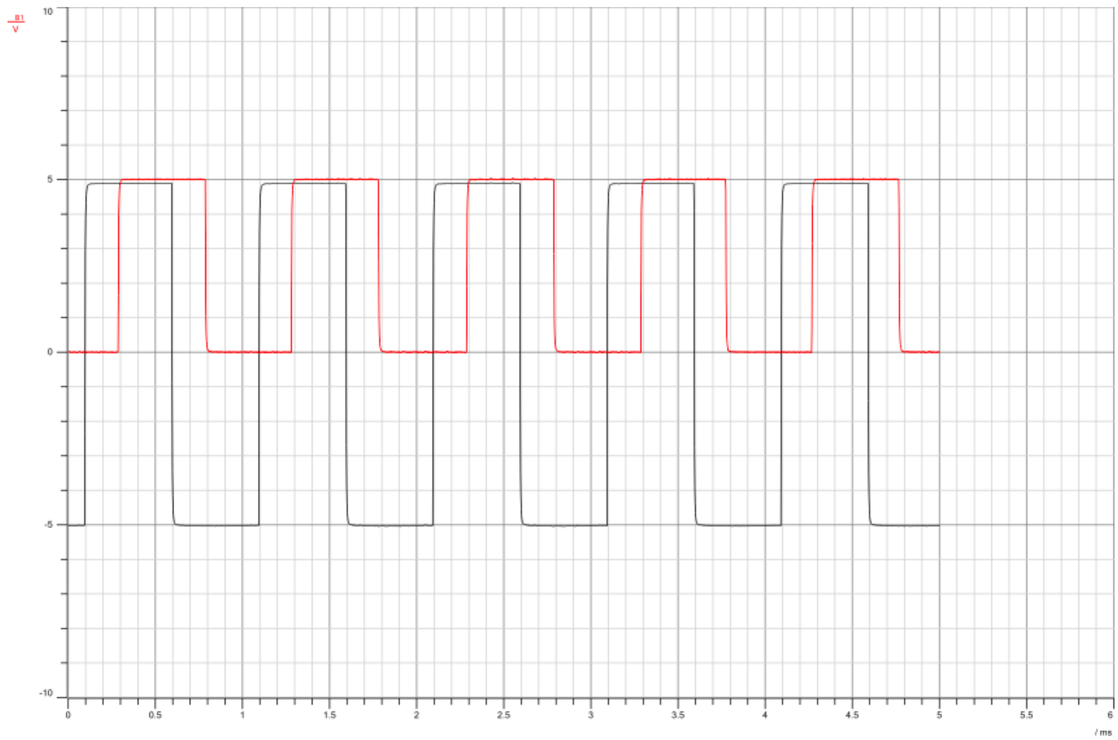

Figure 23: Bipolar message and demodulated signals in Time Domain (Soft keying)

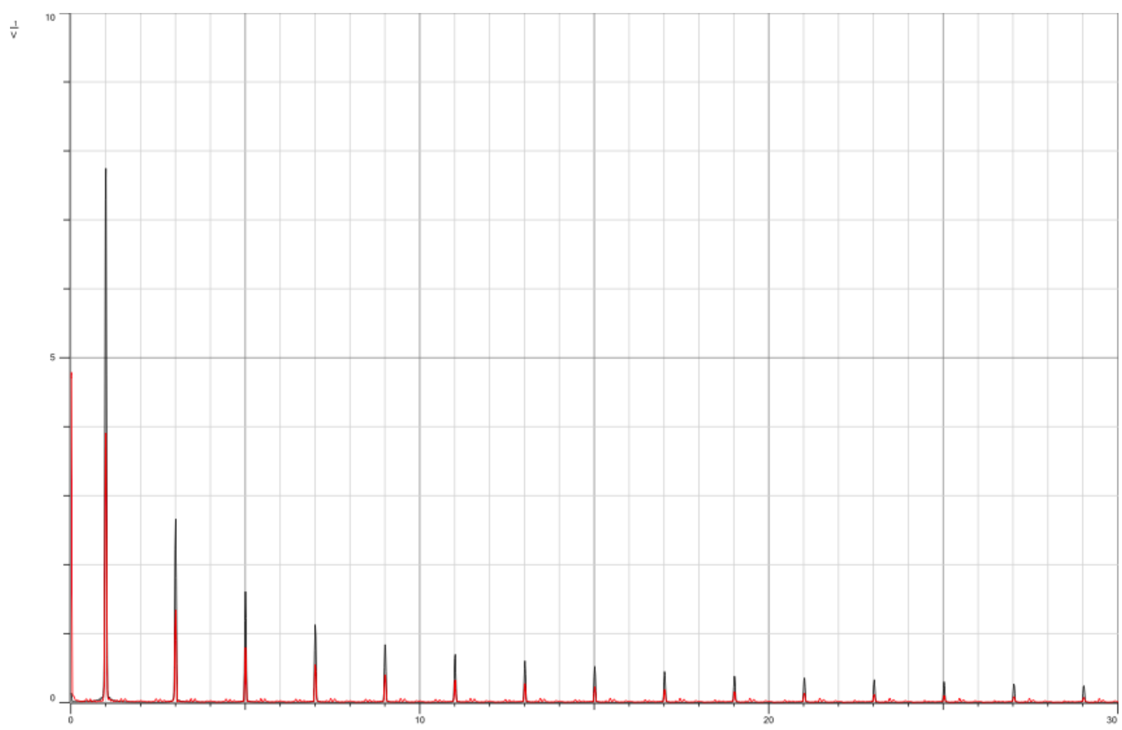

Figure 24: Bipolar message and demodulated signals in Frequency Domain (Soft Keying)

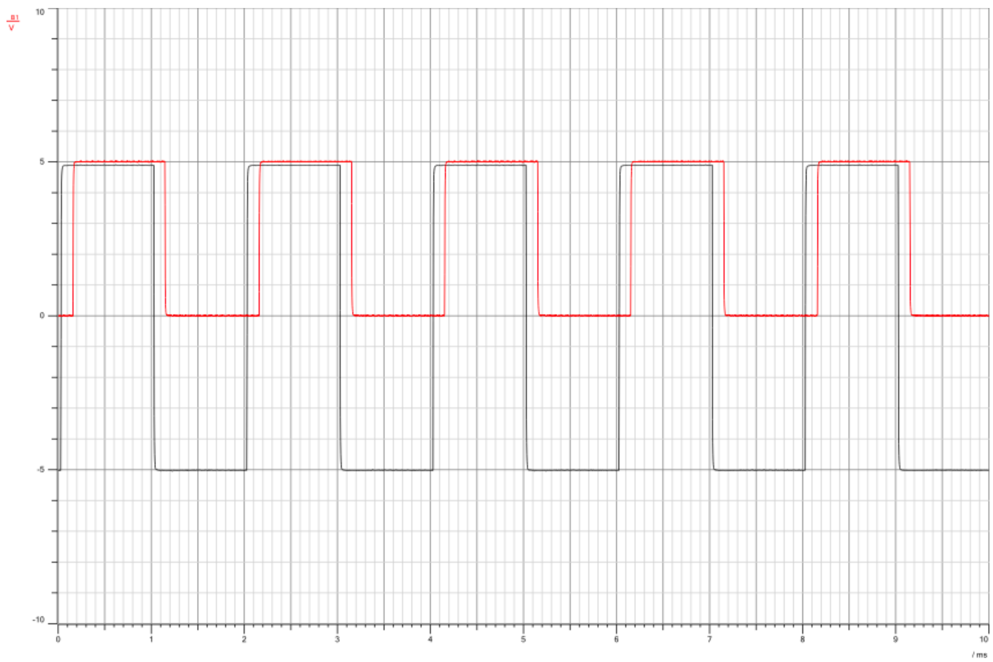

Figure 25: Bipolar message demodulated signals in Time Domain with fm=500hz

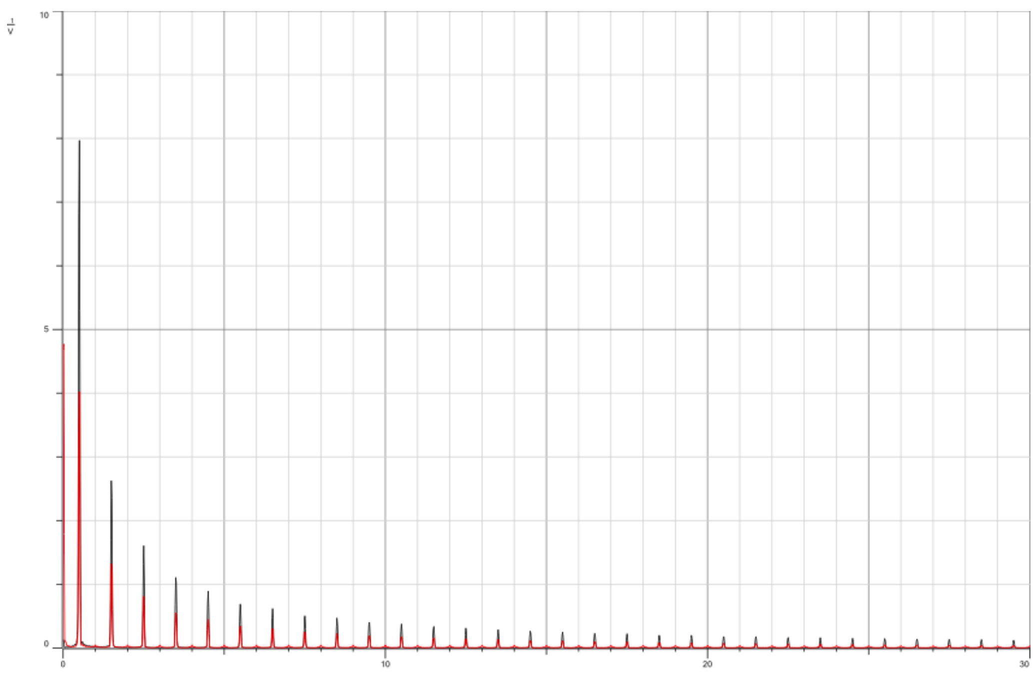

Figure 26: Bipolar message and demodulated signals in Frequency Domain with fm=500hz

When changing the message frequency from 1khz to 500hz, the number of impulses in the frequency domain increases because now there is an impulse every 500hz. We can also see the demodulated signal is closer to the message signal when it has a smaller frequency.

3.3 Phase shift keying Modulation

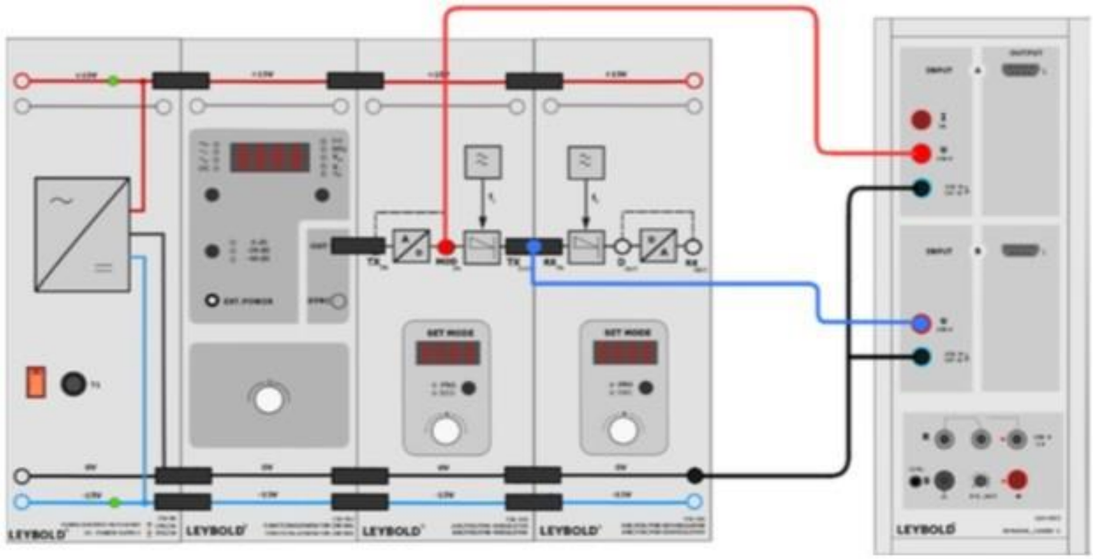

Figure 27: Phase shift keying Modulation Setup [4]

First we Set the function generator to the following settings: Square wave, Freq = 1000 Hz, Vss = 10V, duty cycle = 50%. Then, Set the modulator mode to Digital (DIG). Select Phase shift keying – Hard keying(P_1).

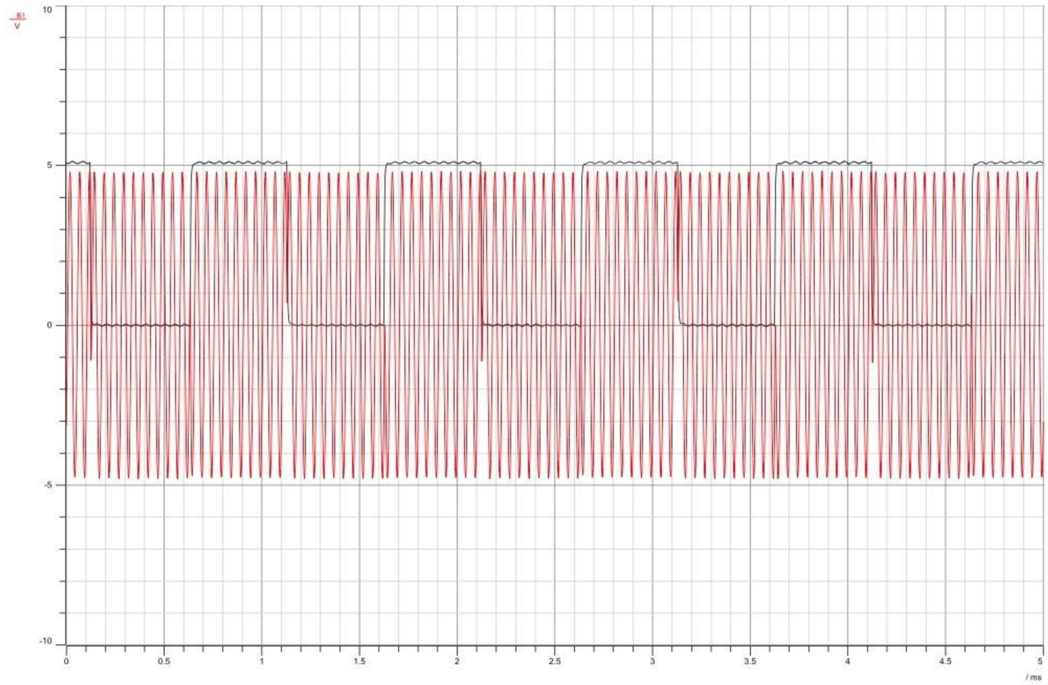

Figure 28: Unipolar signal and Phase Shift Keying Signal (Hard Keying)

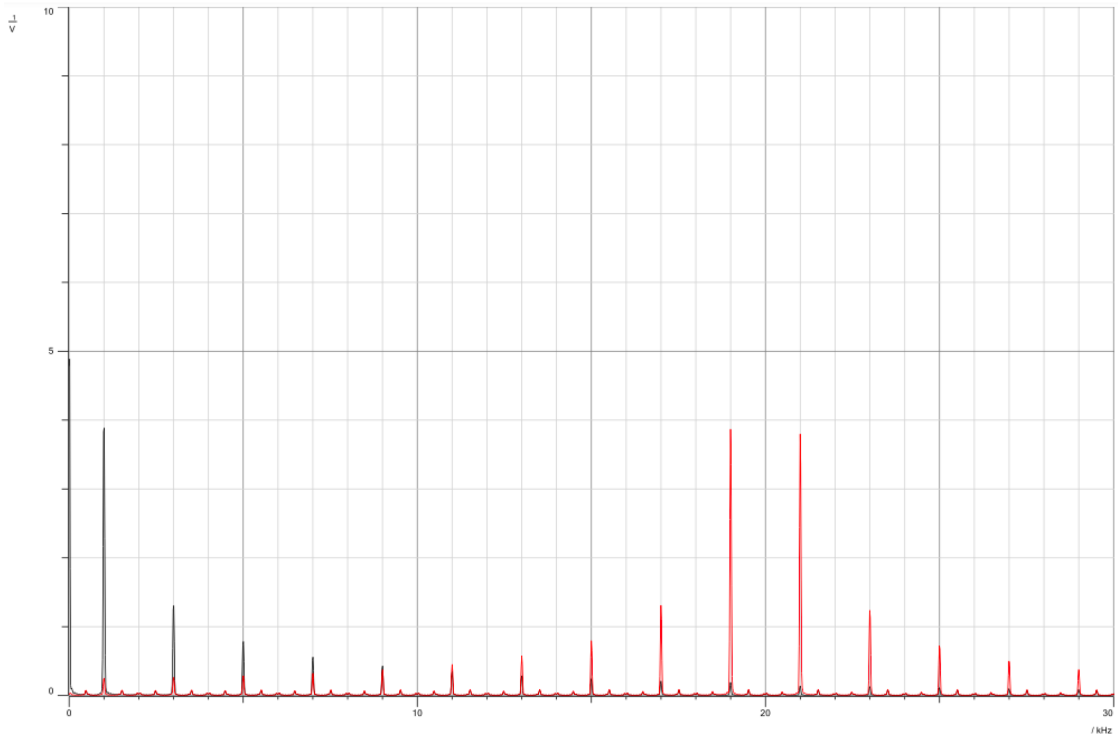

Figure 29: Unipolar signal and Phase Shift Keying Signal in Frequency Domain (Hard Keying)

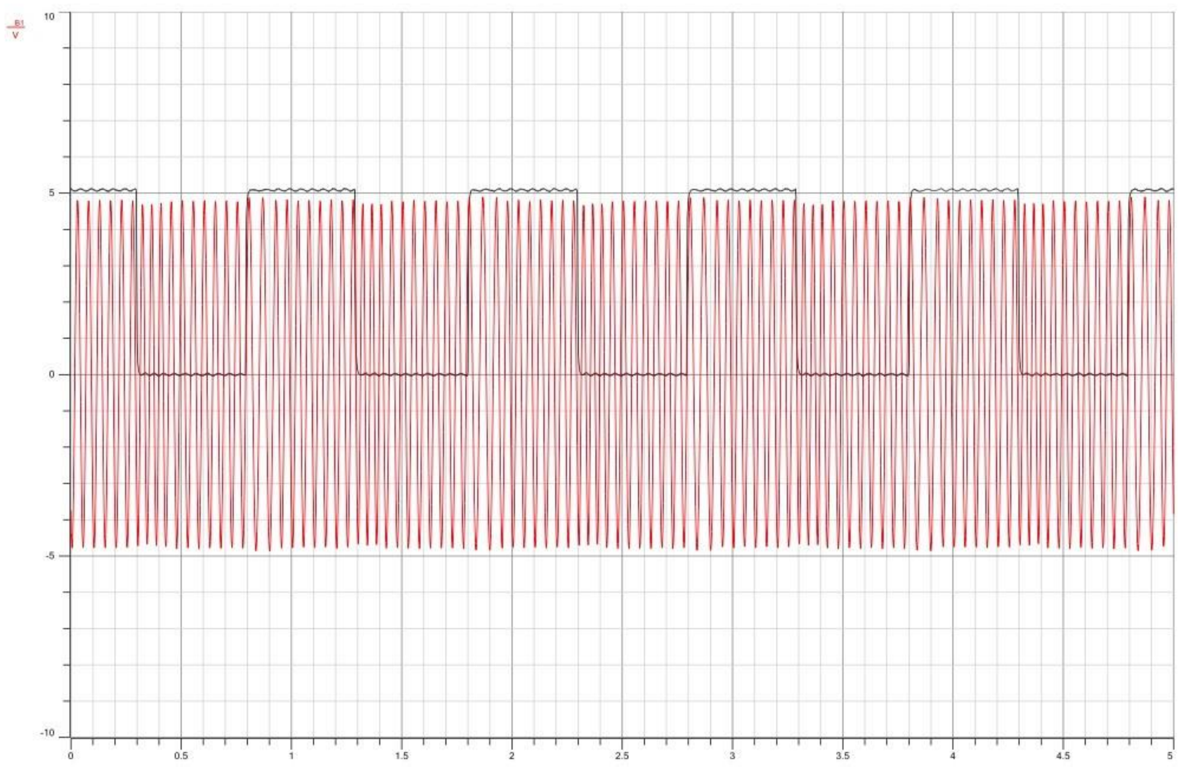

Figure 30: Unipolar signal and Phase Shift Keying Signal (Soft Keying)

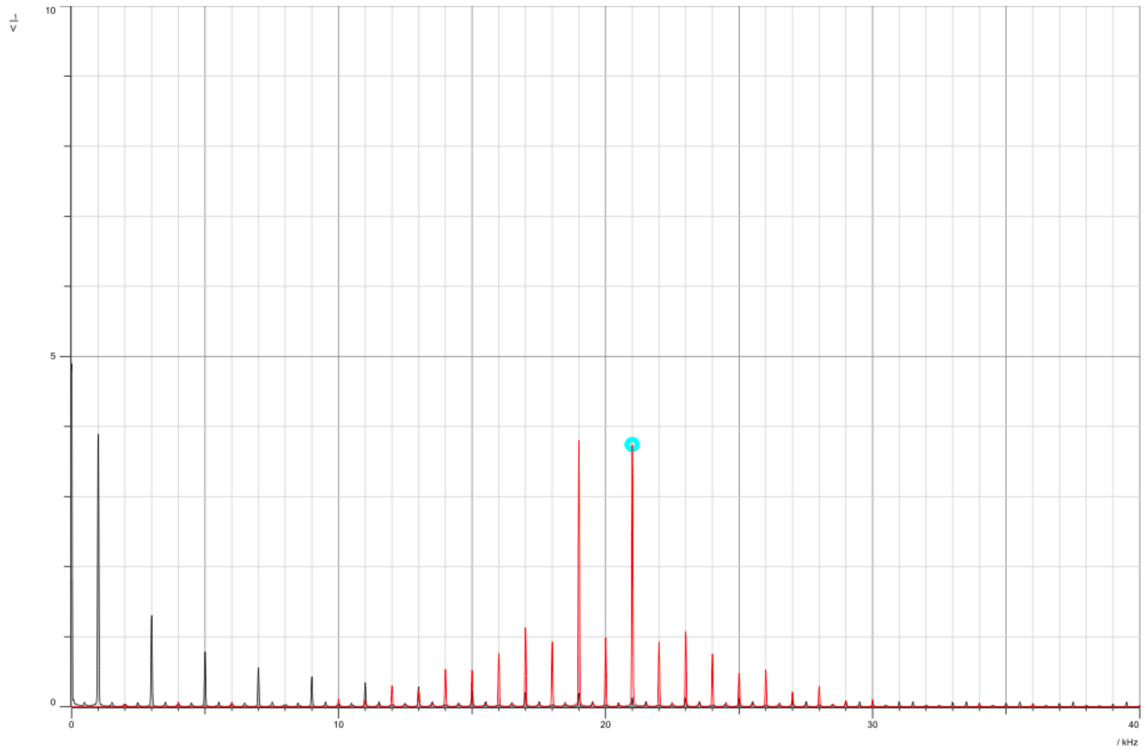

Figure 31: Unipolar signal and Phase Shift Keying Signal in Frequency Domain (Soft Keying)

As can be seen in the figures below, the change happens in the phase of 180 degrees when the digital value changes from zero to one or from one to zero. In hard keying the change happens fast as seen in figure 28, while in figure 30 the change happens slower.

We can see the modulated signal in the frequency domain consists of multiple impulses all around the frequency of the carrier, its envelope shaped like a sinc function. The first Null point that crosses the zero should be at fc+(1/Δ) and fc-(1/Δ). Calculating the bandwidth would give a result = fc+(1/Δ) -- (fc-(1/Δ)) = 2Rb = 2*bitRate.

Now we will see the effect of changing the message signal's amplitude of the modulated signal. We reduce the message signal amplitude to 2v(Vss = 4v).

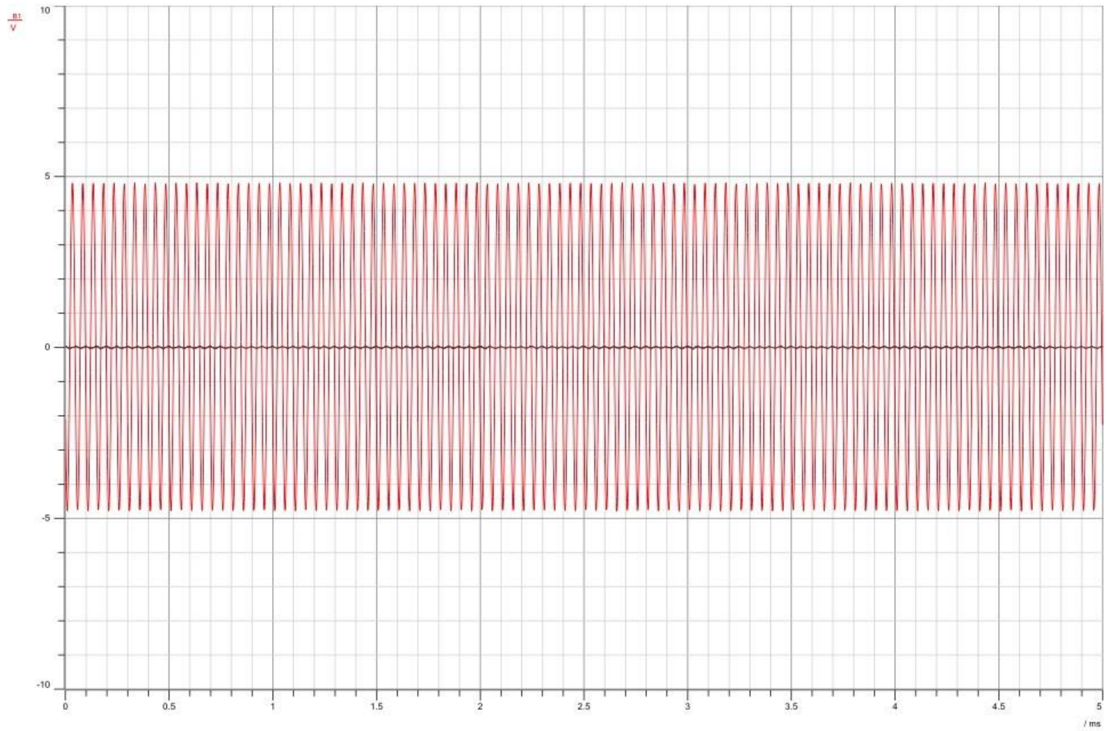

Figure 32: Phase Shift Keying signal with Am=2V

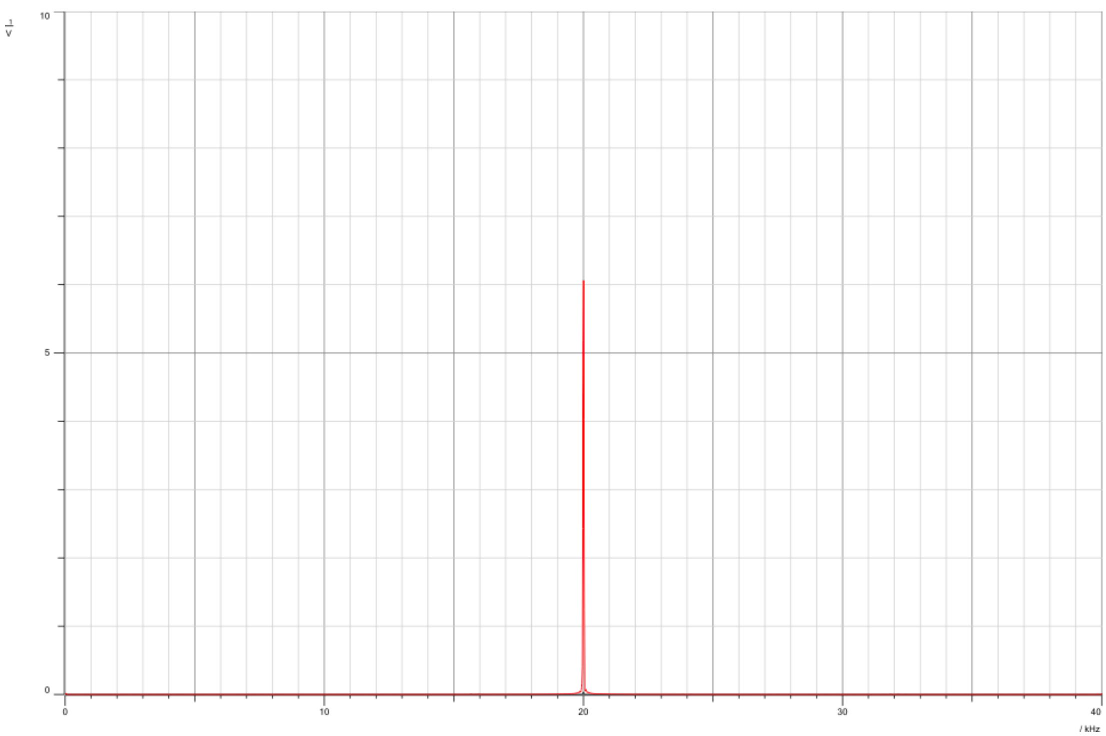

Figure 33: Phase Shift Keying Signal with Am=2V in frequency domain

From the figures above, we realize that changing the message amplitude has no effect on PSK signal. The spectrum stays at 20 khz since changing the amplitude or frequency of the message signal wont show on the phase.

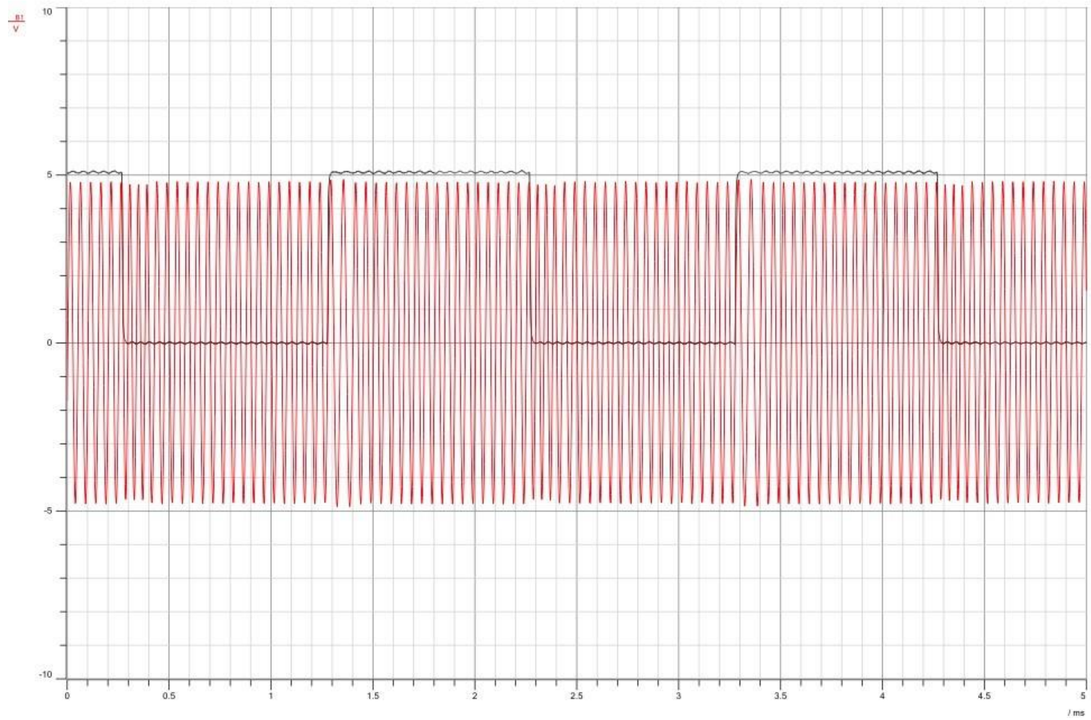

Figure 34: Phase Shift Keying Signal with fm = 500hz

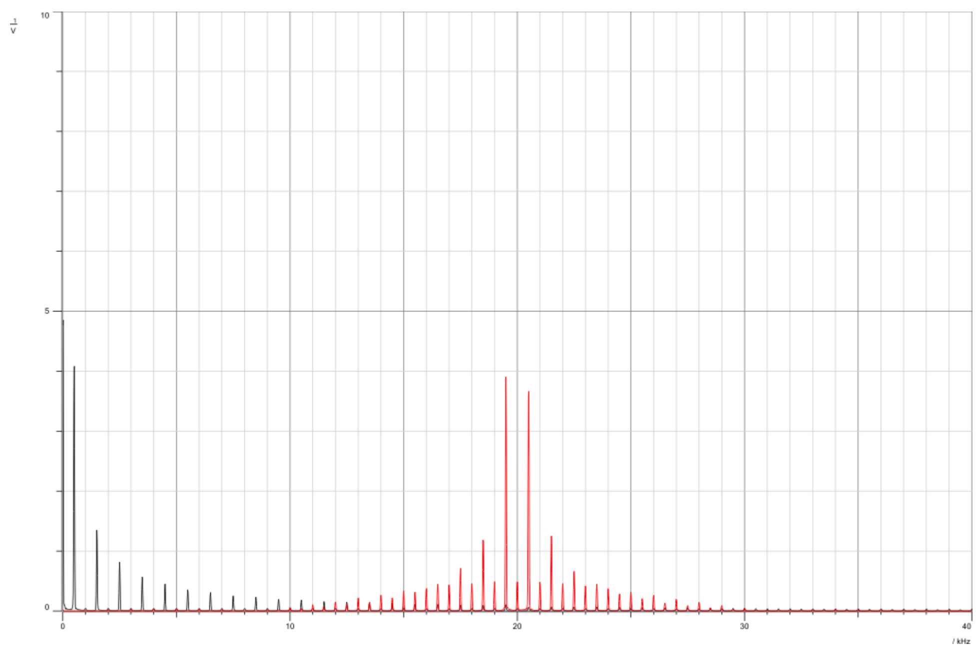

Figure 35: Phase Shift Keying Signal with fm = 500hz in Frequency Domain

As seen in the figures above, changing the frequency of th message signal will increase the number of impulses for the modulated signal PSK. Now we will see the effect of changing the duty cycle on the modulated signal by changing the duty-cycle to 10%. In the figure below, we can see the impulse at the carrier with frequency 20 khz is greatly emphasized compared to figure 35.

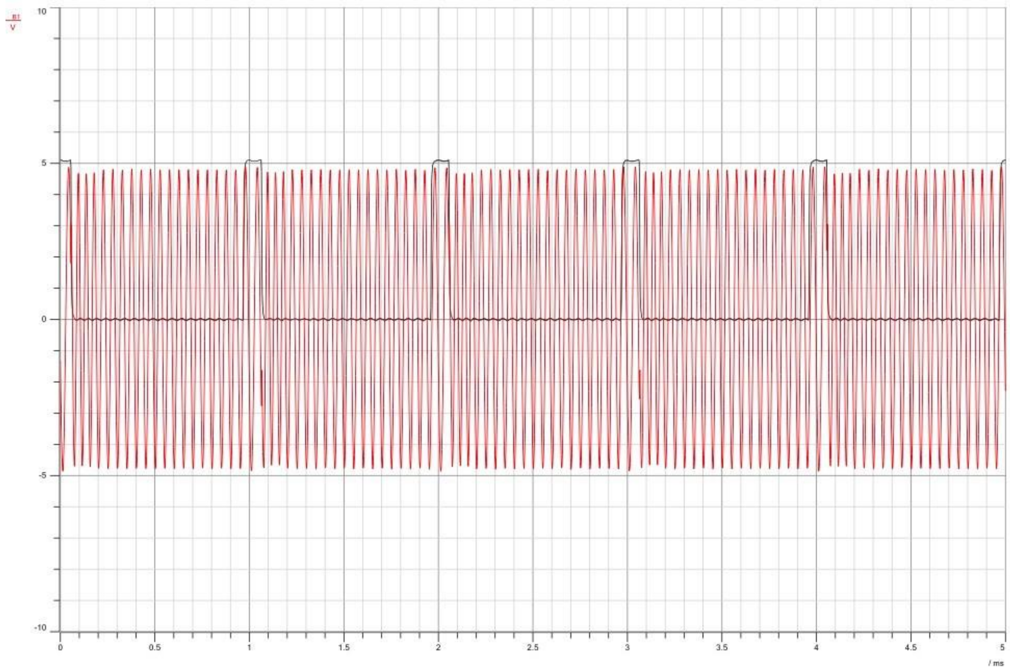

Figure 36: Phase Shift Keying Signal with duty cycle 10%

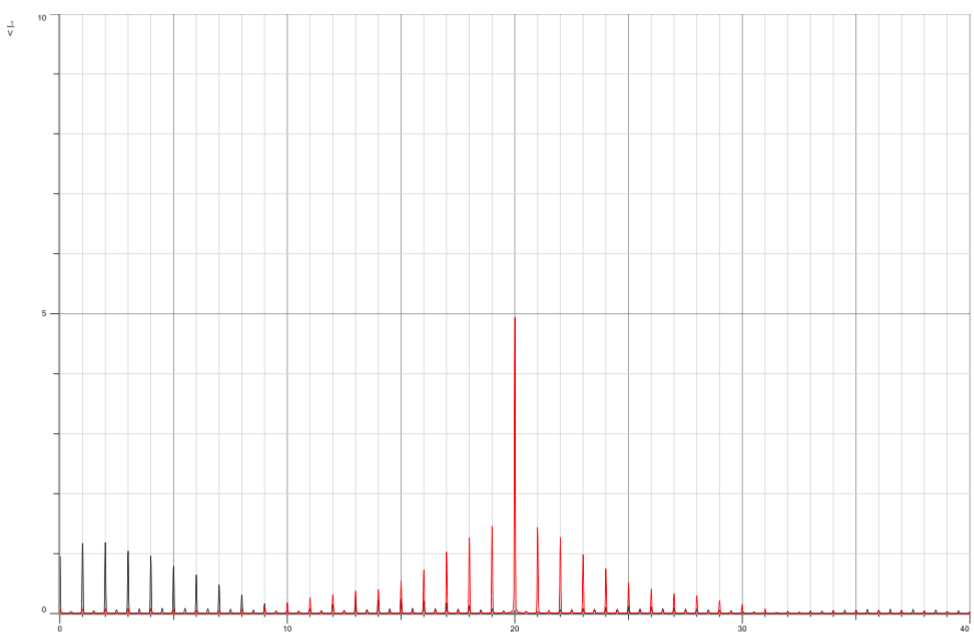

Figure 37: Phase Shift Keying Signal with duty cycle 10% in Frequency Domain.

3.4 Phase shift keying Demodulation

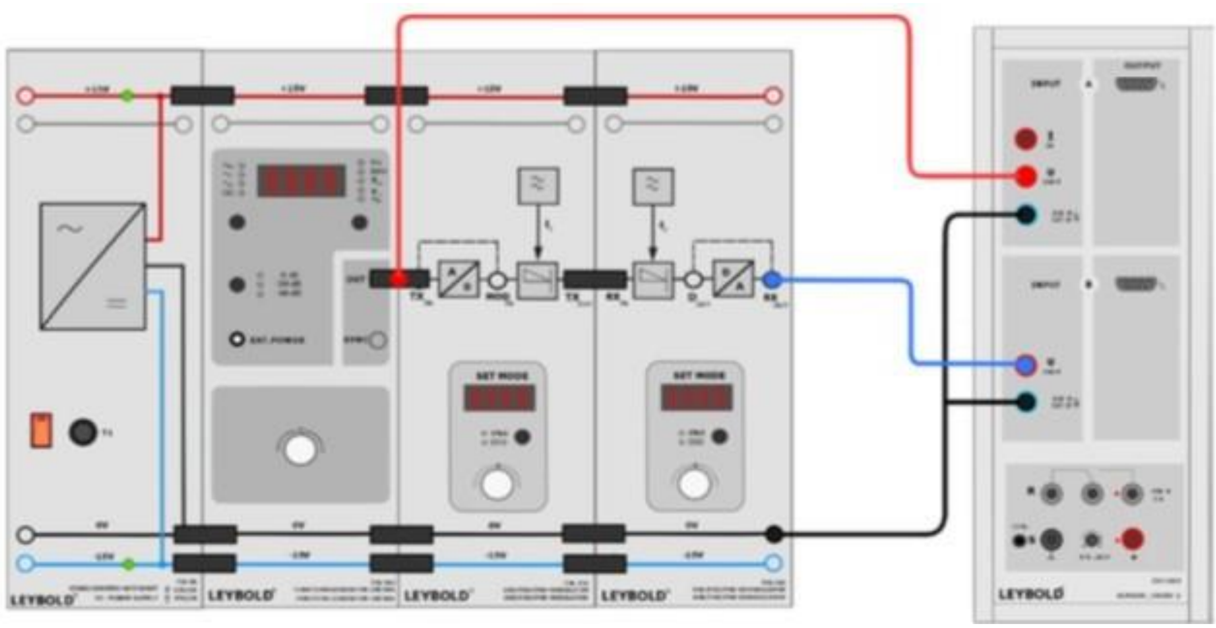

Figure 38: Phase Shift Keying Demodulation Setup [4]

First Set the function generator to the following settings: Square wave, Freq = 1000 Hz, Vss= 10V, duty cycle= 50%. Set the demodulator mode to Digital (DIG). Select the demodulation type (P_1). We must make sure to set the modulator mode to Digital (DIG) AND Select Phase shift keying – Hard keying (P_1).

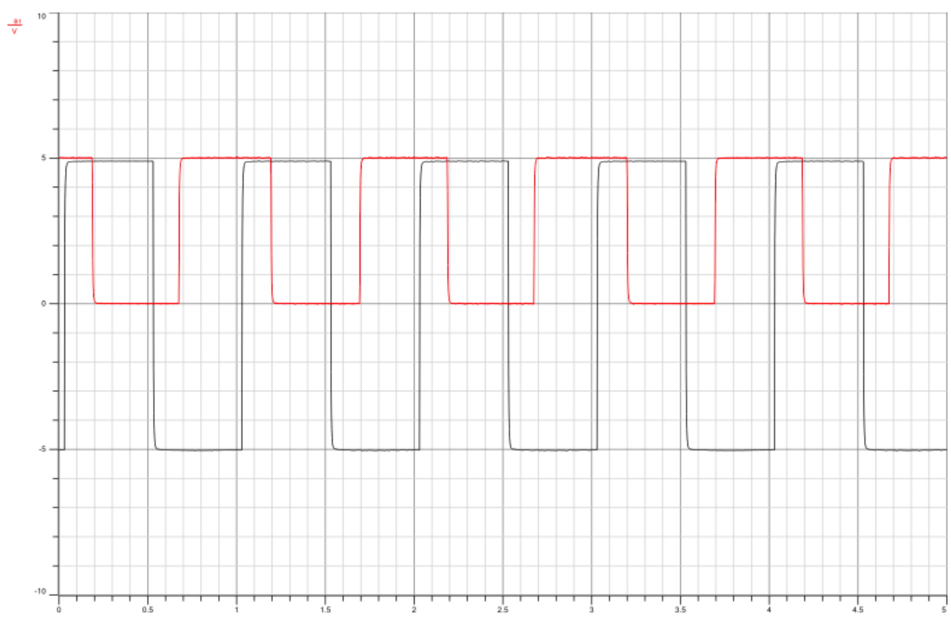

Figure 39: Message and Demodulated Signals (Hard Keying)

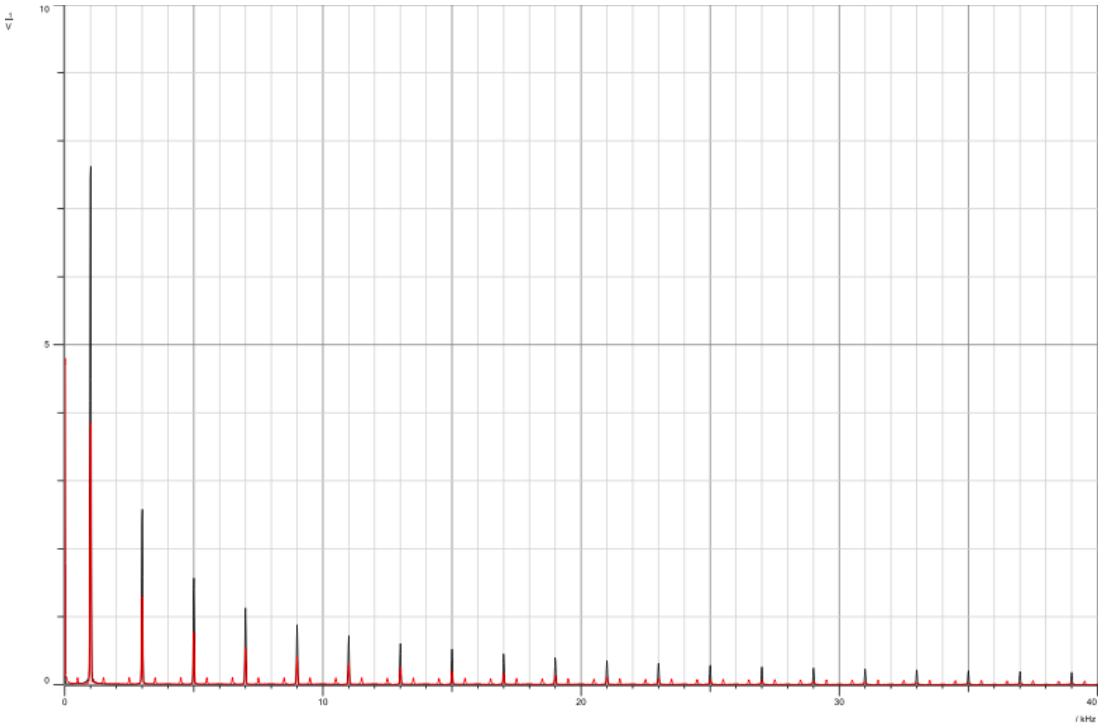

Figure 40: Message and Demodulated Signals in Frequency Domain (Hard Keying)

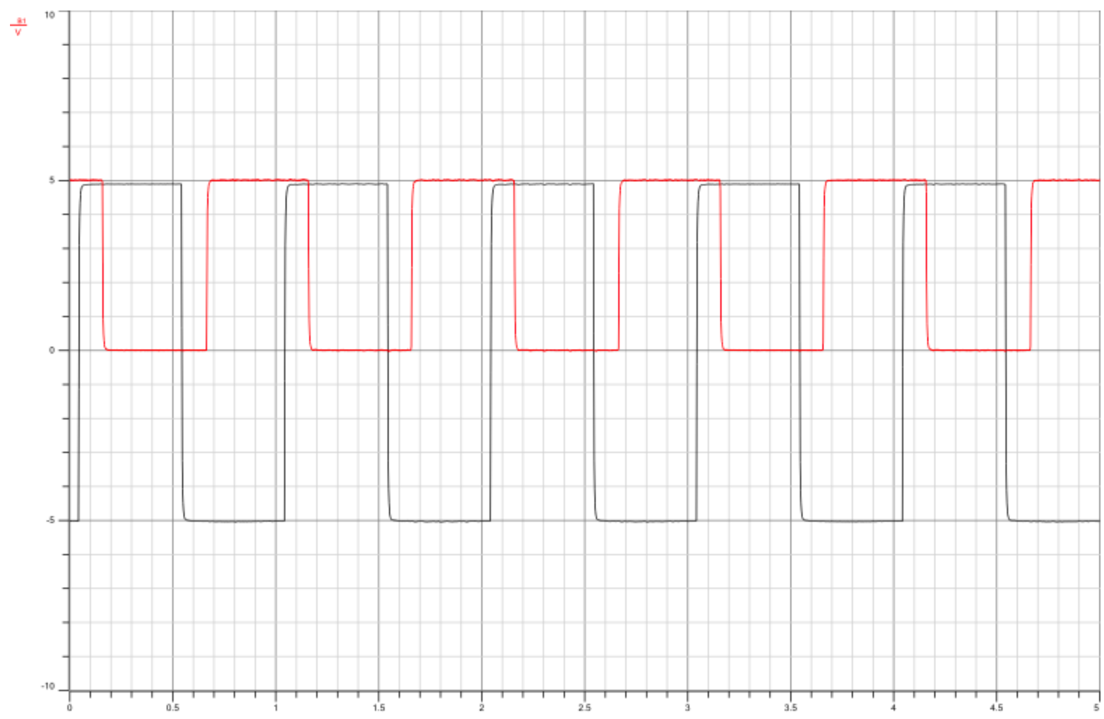

Figure 41: Message and Demodulated Signals (Soft Keying)

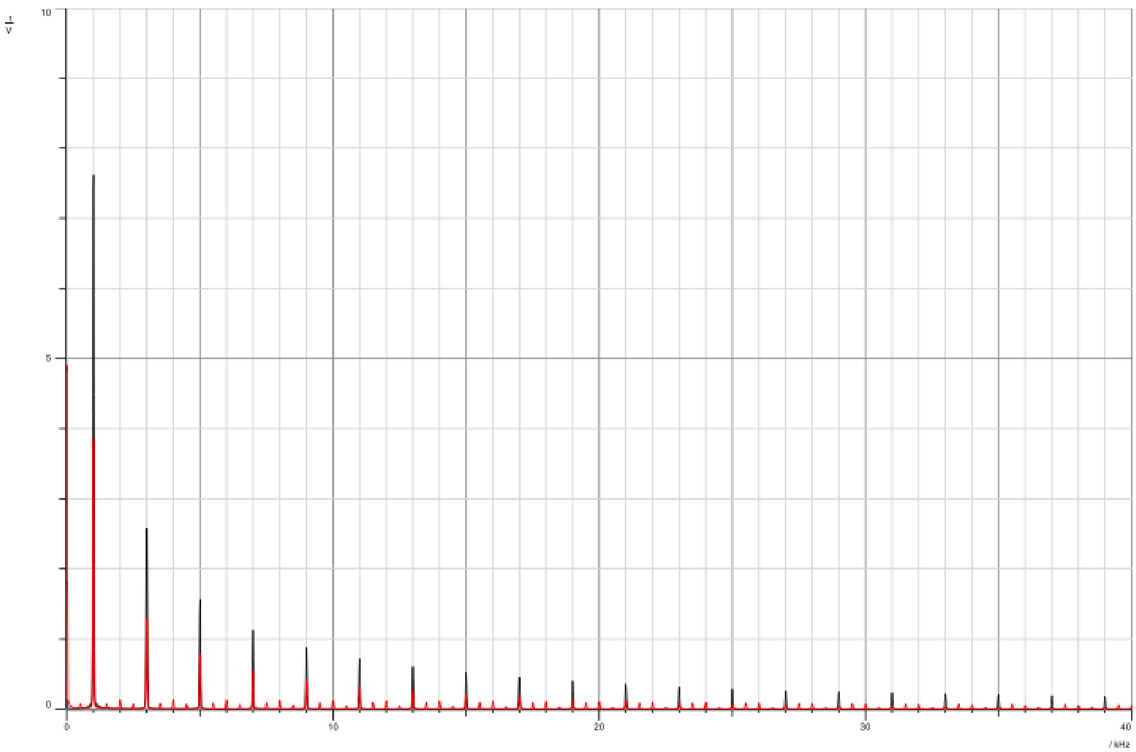

Figure 42: Message and Demodulated Signals in Frequency Domain (Soft Keying)

The pictures for hard keying and soft keying display the demodulated signal a bit shifted compared to the message signal. This happens because there's interference and noise sneaking in. So, the signal we get back has both the message we want and some unwanted noise. But when we look at the frequency parts for both hard and soft keying, we notice that the signal we get back still has the same message frequency as the original one..

The difference in phase shown in the figures between the demodulated signal and the message signal might not only be because of noise and interference. It could also be linked to how the filters work or flaws in the circuits of the modulation and demodulation kits we used in the lab. In a perfect setup, these two signals should have the same phase shift, but that's not always the case in real life setups due to these factors.

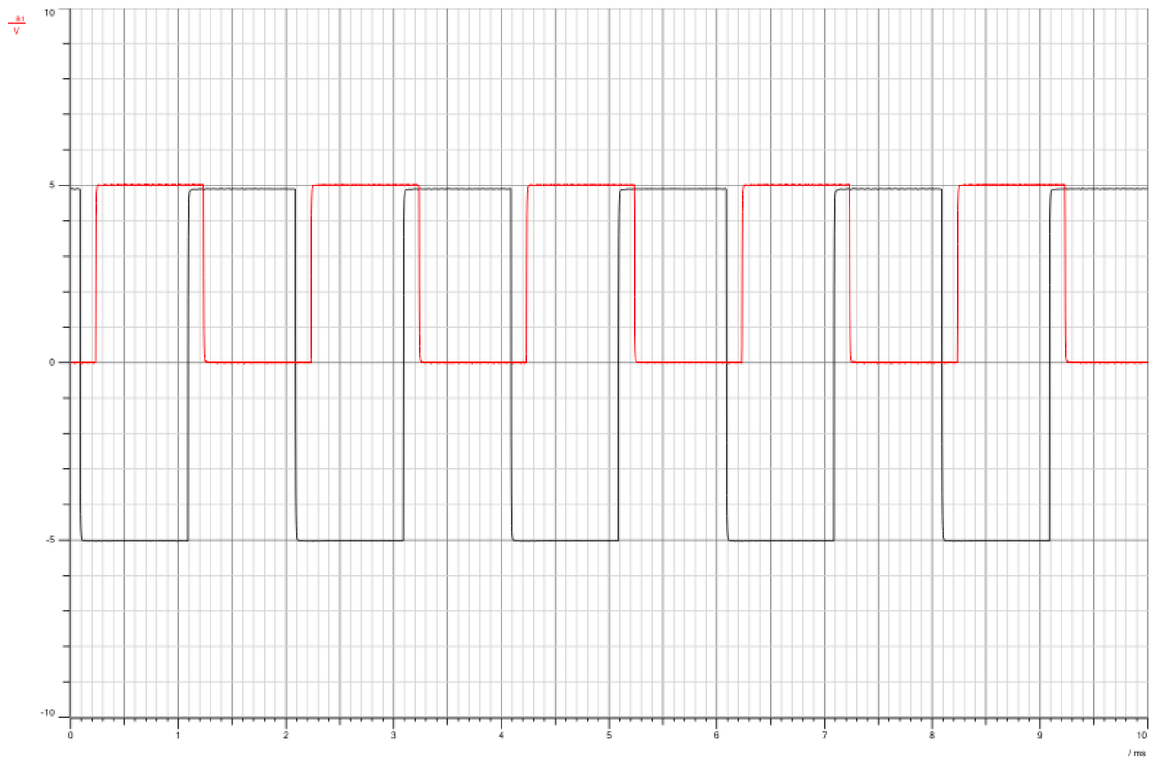

Figure 43: Message and Demodulated Signals with fm=500hz

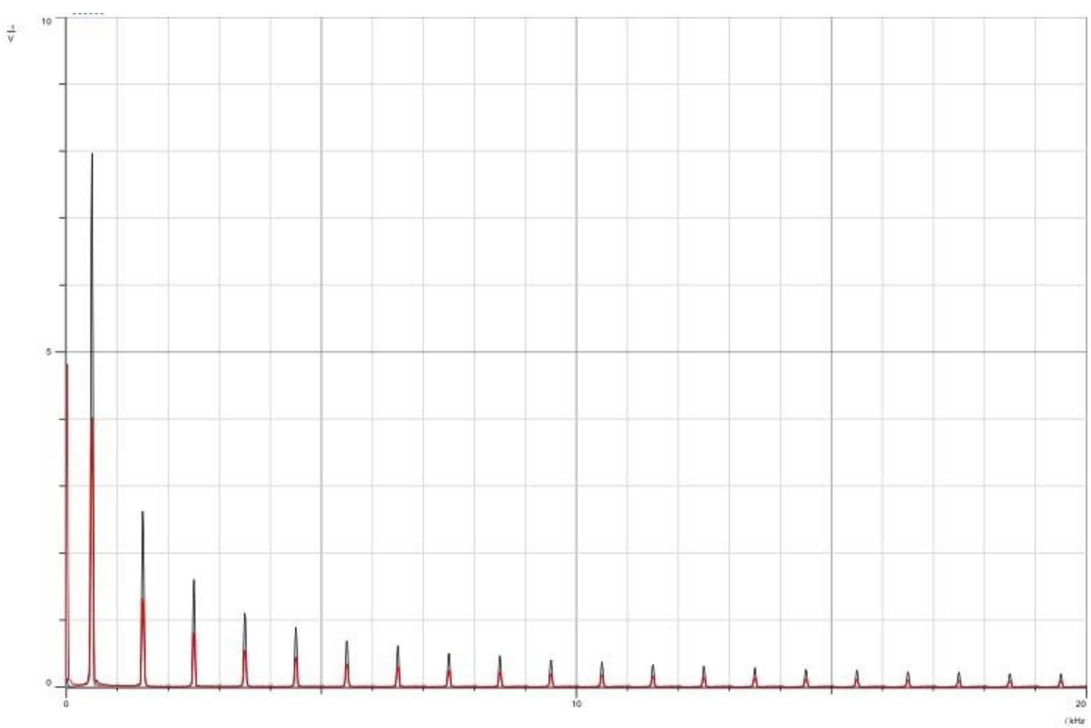

Figure 44: Message and Demodulated Signals with fm= 500hz in Frequency Domain

As can be seen in the figure above, the demodulated signal still has a phase shift compared to the message signal. The demodulation process did succeed in retrieving the message signal with the same frequency but with noise interference. Changing the frequency of the message signal frequency from 1khz to 500hz increased the number of spectral lines. In figure 42 we see 5 spectral lines from 0 to 10khz; however, in figure 44, we see 10 spectral lines from 0 to 10khz.

Conclusion

In this lab, we dived into Frequency Shift Keying and Phase Shift Keying, going deep into their workings. Our experiments vividly highlighted the contrast between soft and hard keying. We explored how the message signal's amplitude, frequency, and duty cycle influence both the time and frequency domains of the modulated signal. Additionally, we delved into the receiver's role (demodulation) and emphasized the significance of the threshold comparator in this process.

References

[1]: Dr.Wael Hashlamoun Communications Slides

[2]:https://www.tutorialspoint.com/digital_communication/digital_communication_phase_shift_keying.htm [Accessed 18 Dec. 2023, 13:22]

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