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Amplitude Modulation/Demodulation Laboratory Report

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Abstract

This laboratory aimed to use mathematical simulating tool MATLAB's Simulink to model and investigate amplitude modulated (AM) signals. Electrical simulation circuits were constructed and simulated to investigate production of an AM signals through modulation and demodulation methods for AM signals. Simulations confirmed the understanding that a modulation index affects the magnitude at which the amplitude is modulated and a modulation index above 1 causes overmodulation. Similarly, the AM signal generating signal was connected to a premade DSB AM demodulator passband and then a simple RC filter coherent demodulator separately and then compared. It was found that when the premade DSB AM demodulator passband used a first order filter the resulting demodulated signals was almost identical to the simple RC filter coherent demodulator, with both showing a distortion, but when the DSB AM demodulator passband allowed for a higher order of the filter which corrected the distortion of the resulting demodulated signal.

Introduction

AM signals underpin many modern communication technologies that involve transference of a message. This is often in the form of an audio signal that is used to produce an AM signal for a radio. These AM signals rely almost solely on the key operation of modulation. Modulation is the process by which a baseband information is shifted to a higher frequency range in preparation for transmission over some physical channel. Modulation can be classified into three types, amplitude modulated (AM), frequency Modulated (FM), and phase modulated. This laboratory investigates amplitude modulation. Demodulation is the reverse process by which a modulated signal is restored to its baseband information. Demodulation can also be classified into two types, coherent and incoherent. This lab investigates the coherent demodulation method.

For simulating and investigating modulation and demodulation the program MATLAB can be used. More specifically, the Simulink aspect can be used to generate, display, and evaluate amplitude modulation and demodulation.

Theory and Preparation work

For message to carried through a communication link you need two main signals, a carrier signal and a message signal. A carrier signal can be defined by Equation 1 [1].

$$x(t) = V_c \cos\,(2\pi f_c t) \qquad \text{(Equation 1)}$$

Where V_c is the maximum amplitude of the carrier signal, and f_c is the maximum frequency of the carrier signal. A message signal can be defined by Equation 2.

$$y(t) = V_t \cos\,(2\pi f_t t) \qquad \text{(Equation 2)}$$

Where V_t is the maximum amplitude of the message signal, and f_t is the maximum frequency of the message signal. Using Equations 1 and 2 the modulated signal can then be represent by Equation 3 [2].

$$v_a(t) = V_c\left(1 + \frac{V_t}{V_c}\cos\,(2\pi f_t t)\right)\cos\,(2\pi f_c t) \qquad \text{(Equation 3)}$$

To better simply and understand this modulation a modulation index can be created and defined as m in Equation 4.

$$m = \frac{V_t}{V_c} \qquad \text{(Equation 4)}$$

Subbing Equation 4 into Equation 3 gives Equation 5

$$v_a(t) = V_c(1 + \mathrm{m}\cos(2\pi f_t t))\cos(2\pi f_c t) \qquad \text{(Equation 5)}$$

The modulation index may also be written as Equation 6 [2]

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \qquad \text{(Equation 6)}$$

Preparation 1

Figure 1: voltage vs time with m=0.5

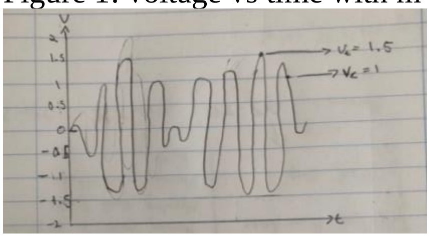


Figure 2: voltage vs time with m = 1

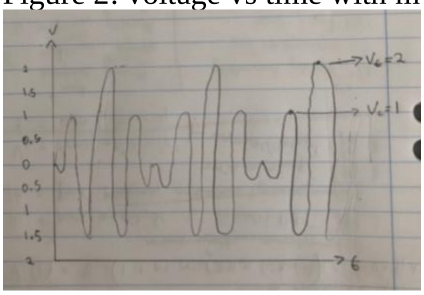
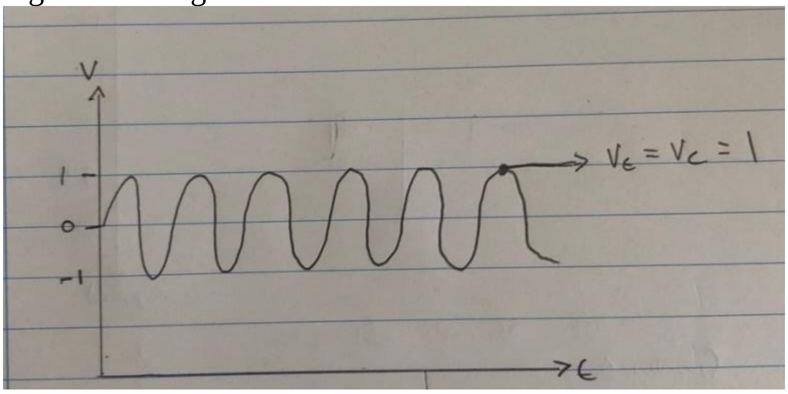


Figure 3: voltage vs time of m=0



Preparation 2

For side frequencies Equation 5 can be rewritten as:

$v_a(t) = V_c \cos\,(2\pi f_c t) + \frac{mV_c}{2} \cos\,(2\pi(f_c - f_t)t) + \frac{mV_c}{2} \cos\,(2\pi(f_c + f_t)t)$ (Equation 7)

Using Equation 7

Figure 4: voltage vs frequency with m= 1

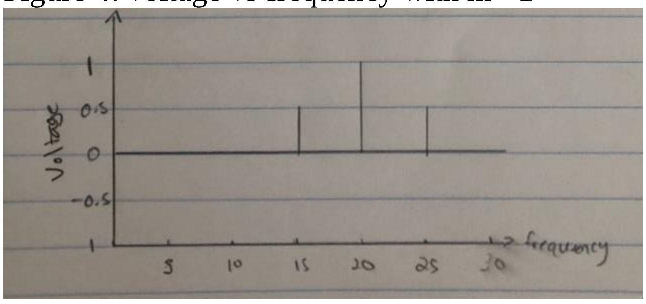


Figure 5: voltage vs frequency with m= 0

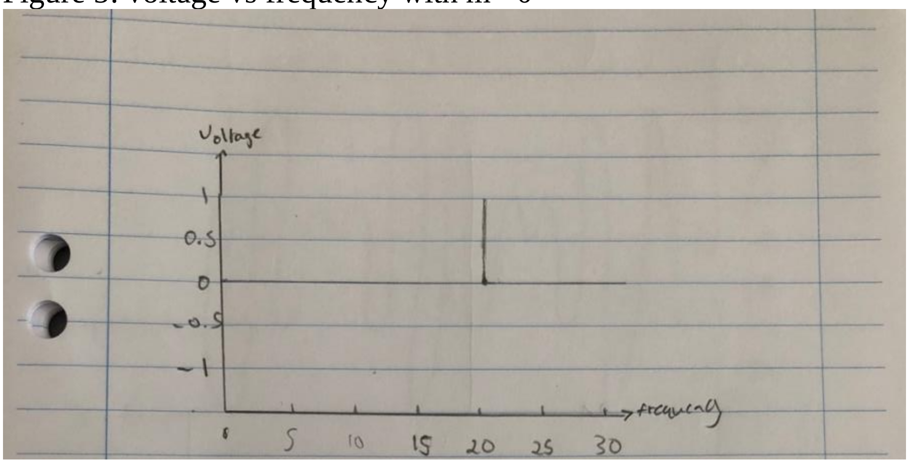


Figure 6: voltage vs frequency with m= 0.5

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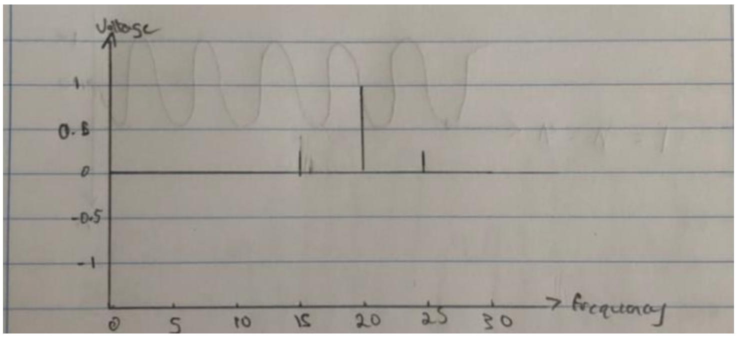


Figure 7: power vs frequency with m= 0

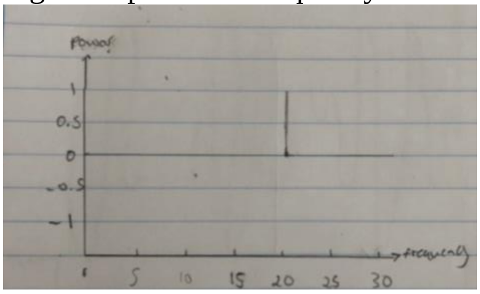


Figure 8: power vs frequency with m= 1

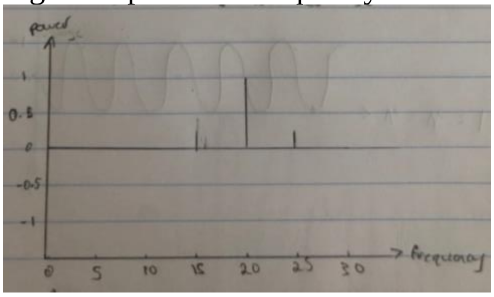
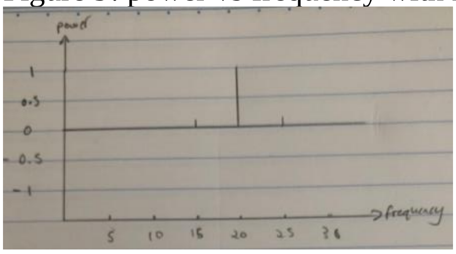
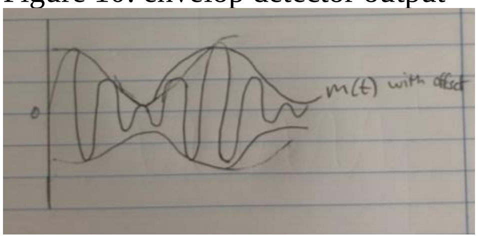


Figure 9: power vs frequency with m= 0.5



Preparation 3

Figure 10: envelop detector output



Results and Discussion

4.1 – Generate and Display Wave form

To generate the carrier and message signal, sinusoidal sources were used; Figure 11. The parameters for these sources can be seen with Figure 12 for the message signal and Figure 13 for the carrier signal. These values are the same as the values used in the preparatory work.

Figure 11: Circuit of message and carrier signal

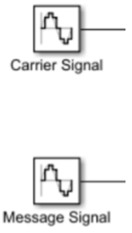


Figure 12: Parameter of message signal

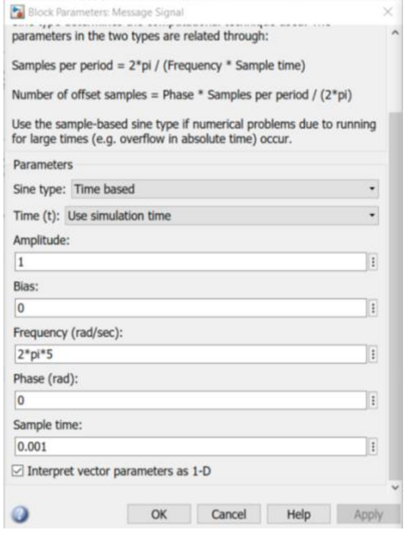
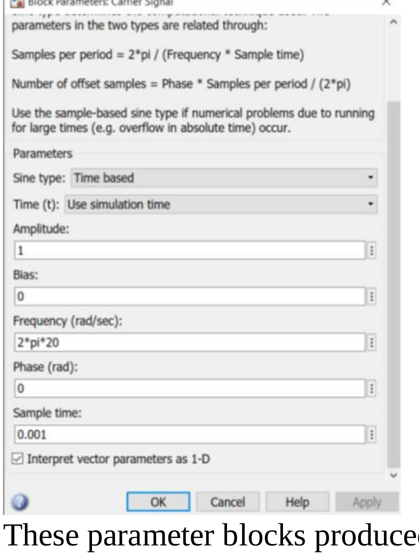


Figure 13: Parameters of carrier signal



These parameter blocks produced the wave forms in Figure 14 and 15

Figure 14: Waveform of message signal

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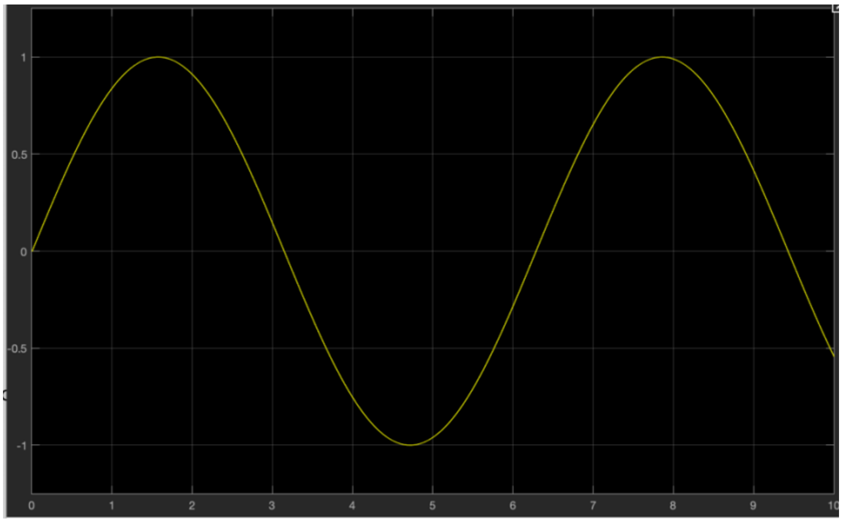
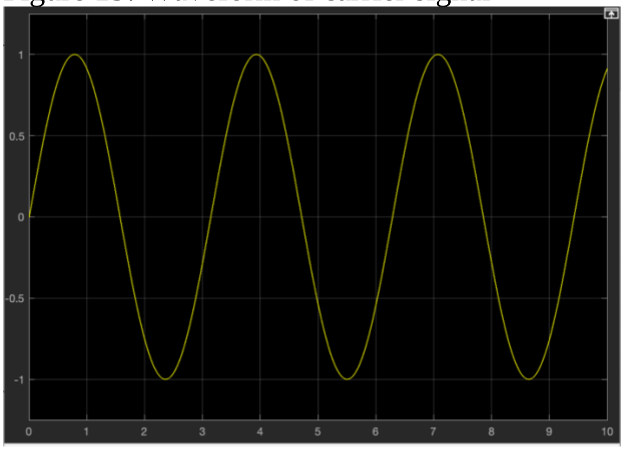


Figure 15: Waveform of carrier signal

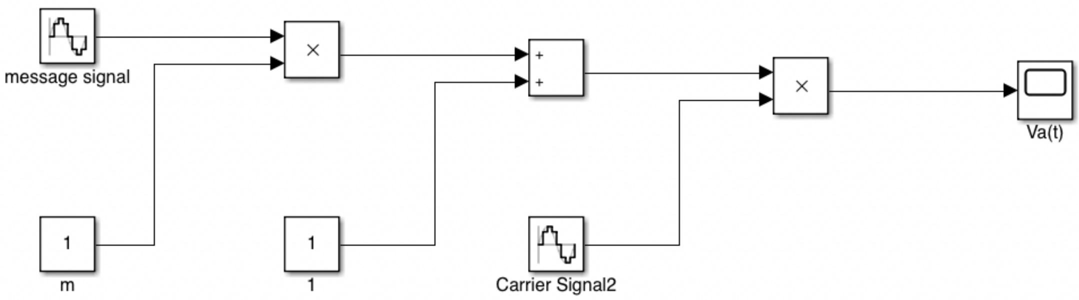


Question 1:

The required blocks to create the system from Equation 5, are constant, carrier signal, message signal

4.2 – Modulation Index and Modulation Scaling

Question 2:



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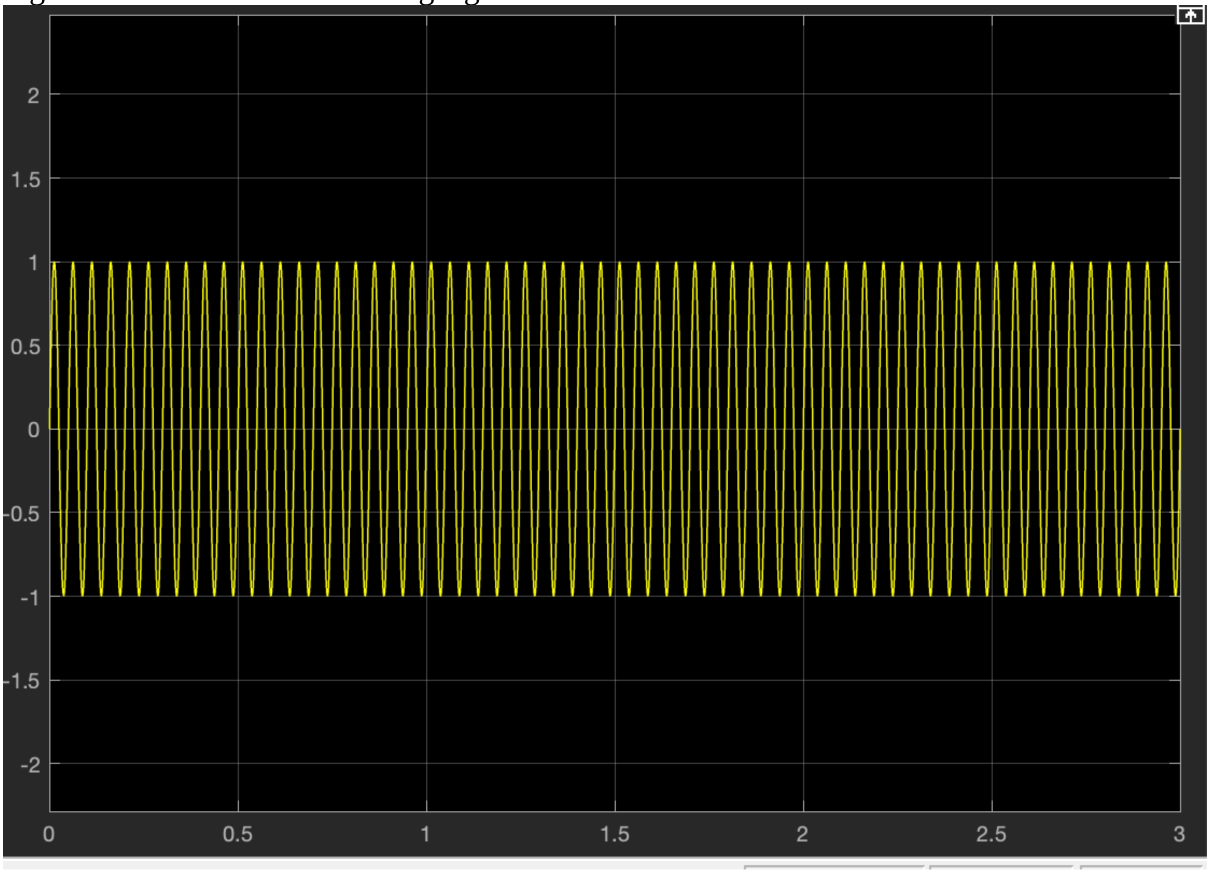
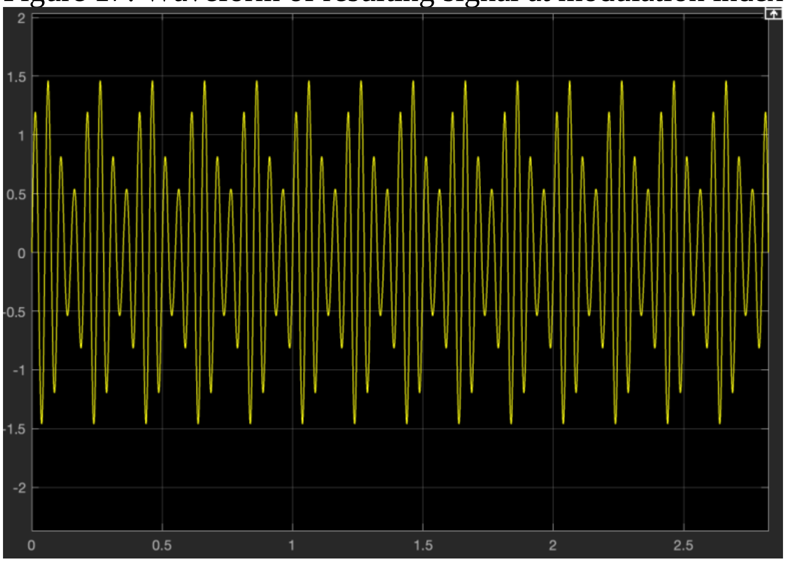
Question 3

Figure 16: Waveform of resulting signal at modulation index 0%



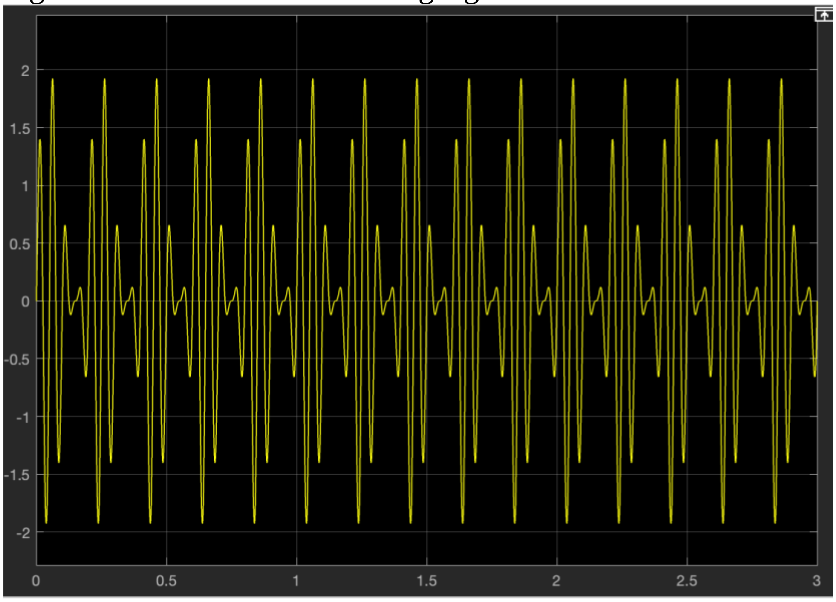
With a modulation index of 0 the wave from Figure 16 is identical to the carrier wave as no modulation has occurred. Consulting equation 5 it is also mathematically agreeing. This straight line in the envelope detection and therefore is offset by V_{max}.

Figure 17: Waveform of resulting signal at modulation index 50%



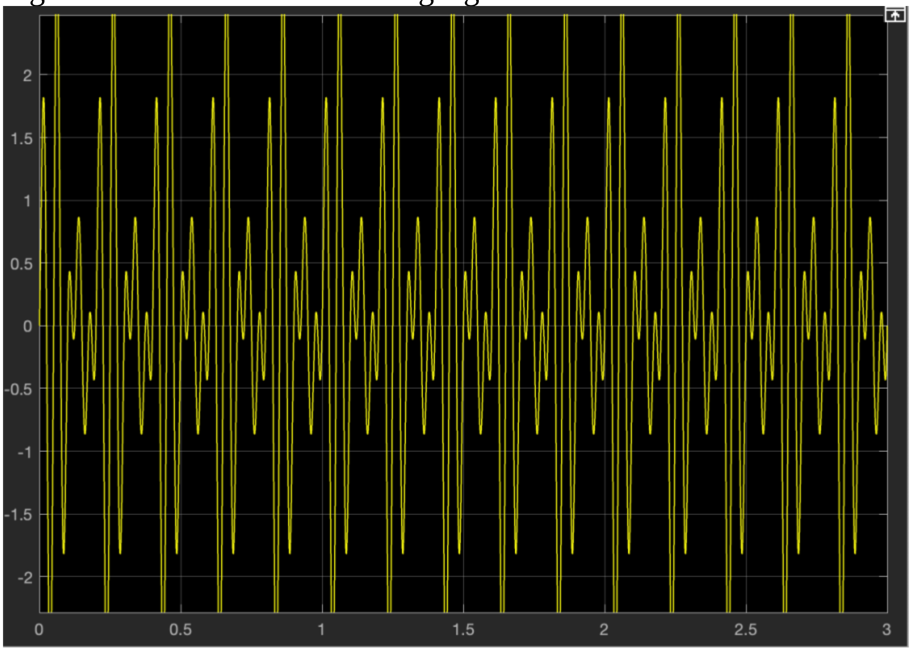
With modulation index of 0.5 the wave from Figure 17 the figure above has maximum amplitude is 1.5x the original signals maximum amplitude. In addition, there is a sinusoidal curve in the envelope detection that is offset by V_{max}.

Figure 18: Waveform of resulting signal at modulation index 100%



With modulation index of 1 the wave from Figure 18 the figure above has maximum amplitude is 2x the original signals maximum amplitude. In addition, there is a sinusoidal curve that reaches zero in the envelope detection that is offset by V_{max}.

Figure 19: Waveform of resulting signal at modulation index 200%



With modulation index of 2 the wave from Figure 19 the figure above has been distorted. Which would not properly allow for demodulation.

4.3 AM Waveform Frequency Spectrum

Figure 20: Frequency behaviour 0%

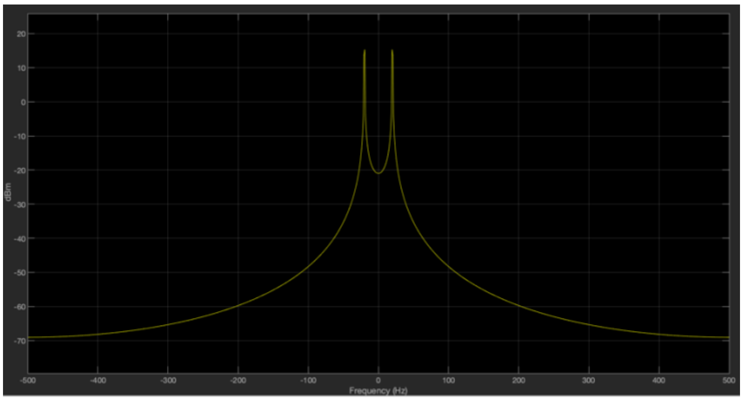


Figure 21: Frequency behaviour 50%

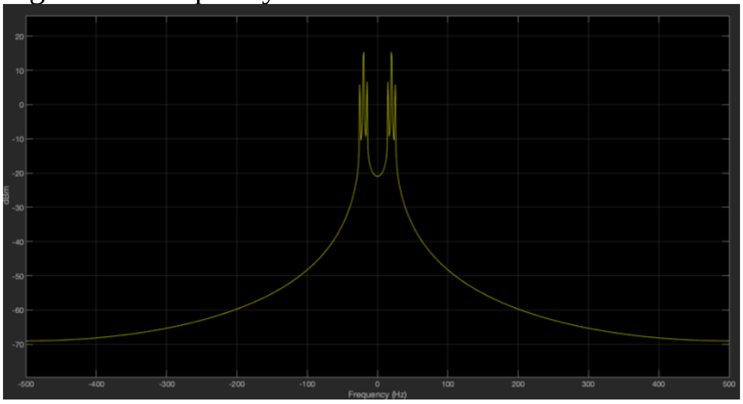
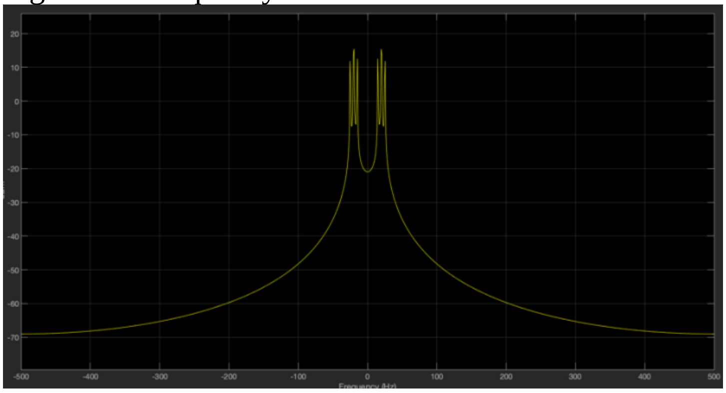


Figure 22: Frequency behaviour 100%



For 0% it can be seen from Figure 20 that for positive and negative frequency there was a single peak at about 20Hz. This is to be expected as the carrier signal is 20 Hz. For 50% and 100% there is the peak at 20 Hz but where are also other peaks next to the two 20Hz peaks. These are due to side frequencies namely the low side frequency and the high side frequency. The power at which these occur are proportionally related to the modulation index. This is corroborated with the findings above.

4.4 Demodulation of AM waves

To investigate demodulation the premade DSB AM demodulator passband was first used by adding it to a generated AM signal with parameters found in Figure 23 giving a circuit seen in Figure 24.

Figure 23: Parameters for DSB AM demodulator passband

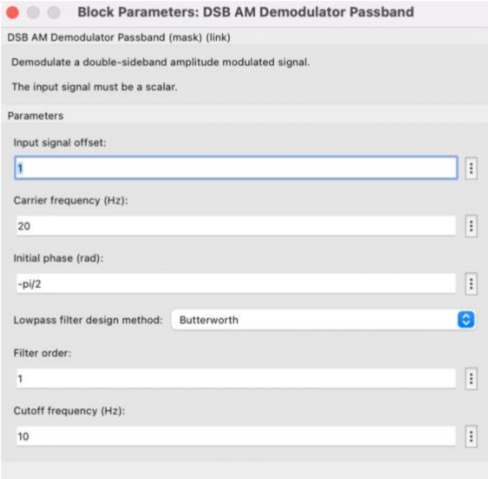
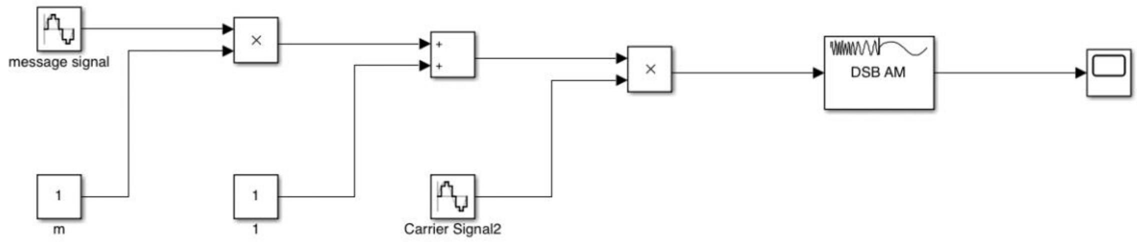
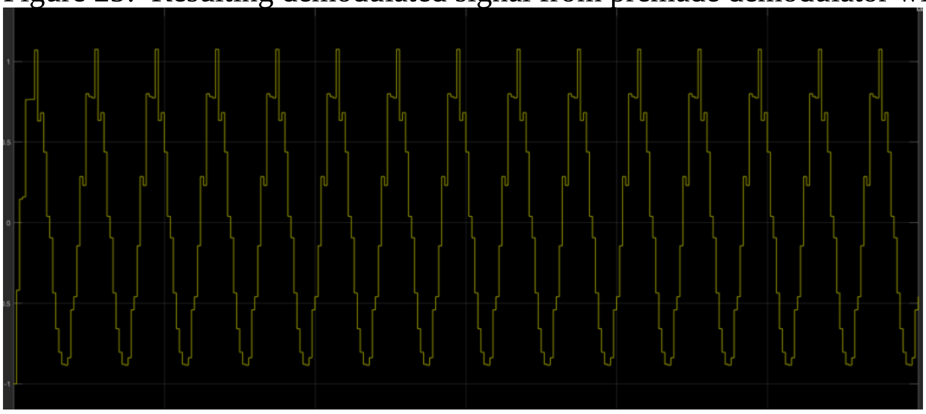


Figure 24: Circuit of AM signal with DSB AM demodulator passband



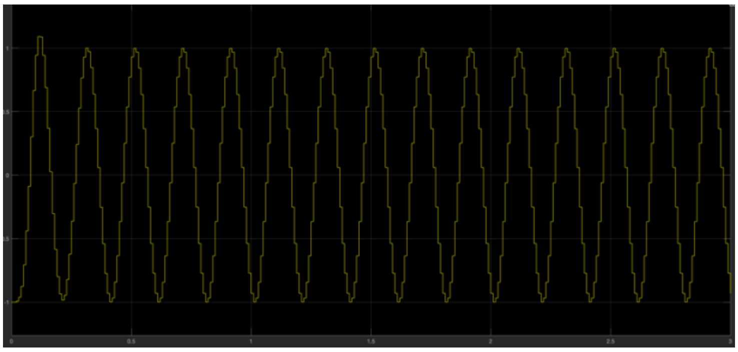
The resulting signal seen at the scope gives Figure 25.

Figure 25: Resulting demodulated signal from premade demodulator with a filter order of 1



This result shows an aspect of distortion (graph is slightly translated vertically) which is probably due to the filter used is only first order. From research the higher the order of the filter will mitigate the distortion [3]. This circuit was then re-simulated using a filter order of 6 on the demodulator block producing Figure 26

Figure 26: Demodulated signal from premade demodulator with filter order of 6



This resulting signal has peaks at 1 and -1V which is the range in which the signal should exist.

Question 4

For this question a coherent demodulation method was used. This was done by multiplying the generated AM signal by the carrier signal (for a more ideal result) and then passed through a simple RC filter. The RC filter was simulated using a transfer function block as seen in Figure 27, producing a resulting demodulated signal of Figure 28.

Figure 27: Circuit for coherent demodulation with RC filter

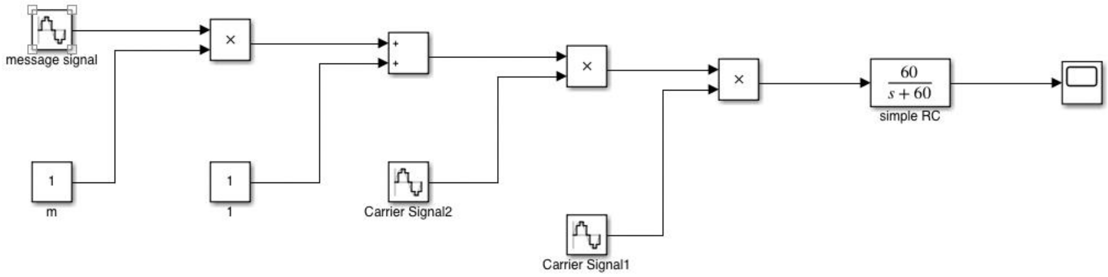
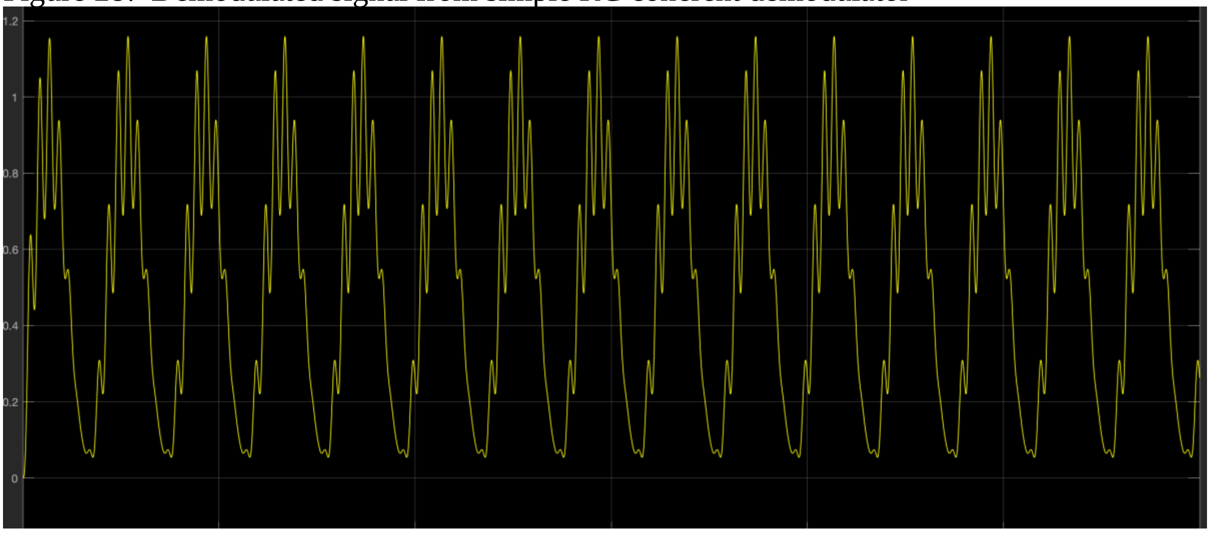


Figure 28: Demodulated signal from simple RC coherent demodulator



The Demodulated signal from Figure 28 shows distortion. Like the DSB AM demodulator passband, this is most likely due to the simple RC filter being a first order filter.

4.5 Noise

Figure 29: spectrum analysis with a noise power of 0.1 for the white noise generator

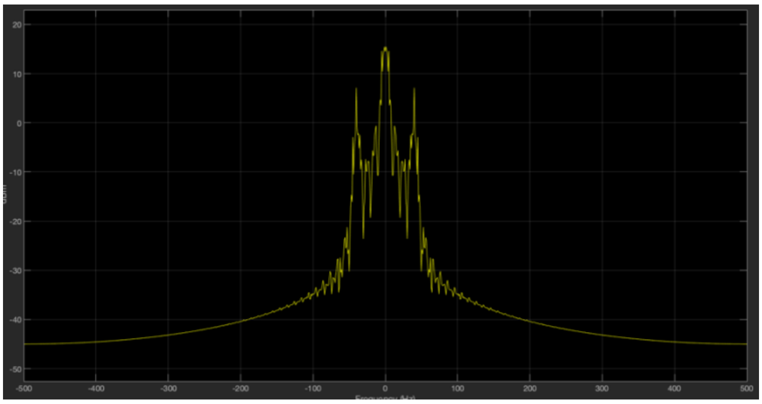


Figure 30: resulting demodulated wave with a noise power of 0.1 for the white noise generator

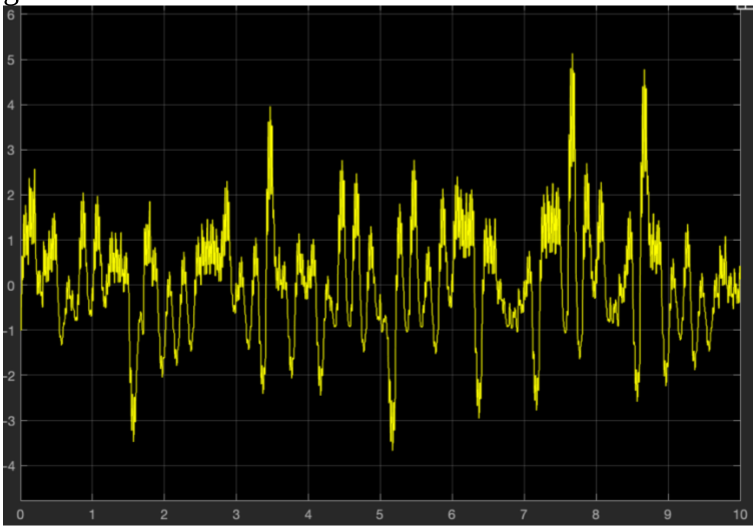


Figure 31: spectrum analysis with a noise power of 0.01 for the white noise generator

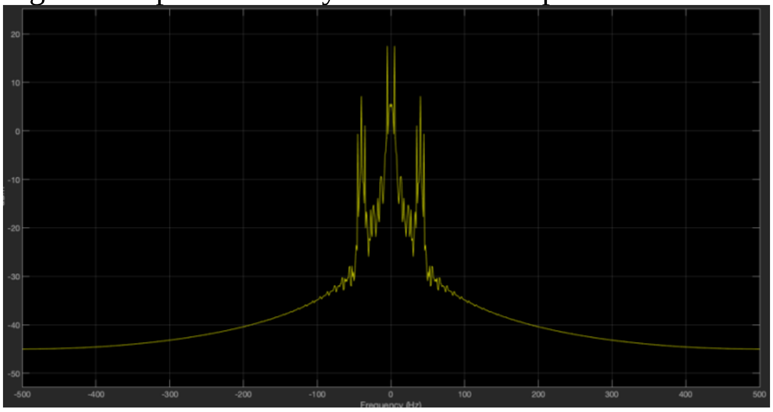


Figure 32: resulting demodulated wave with a noise power of 0.01 for the white noise generator

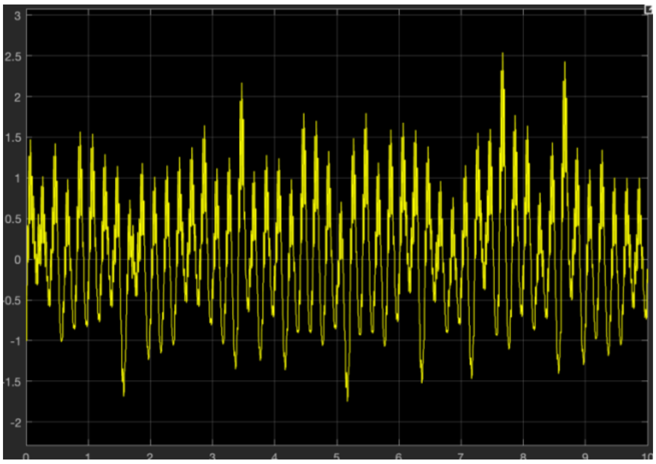


Figure 33: spectrum analysis with a noise power of 0.001 for the white noise generator

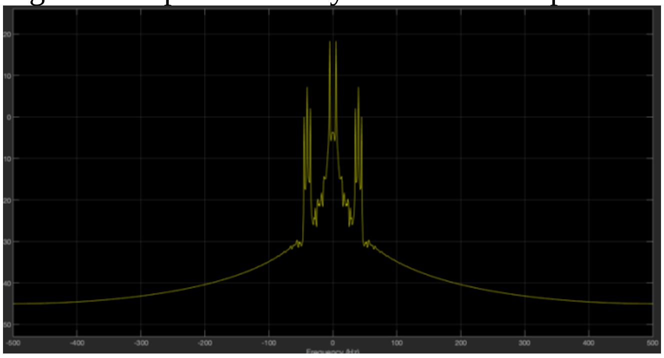
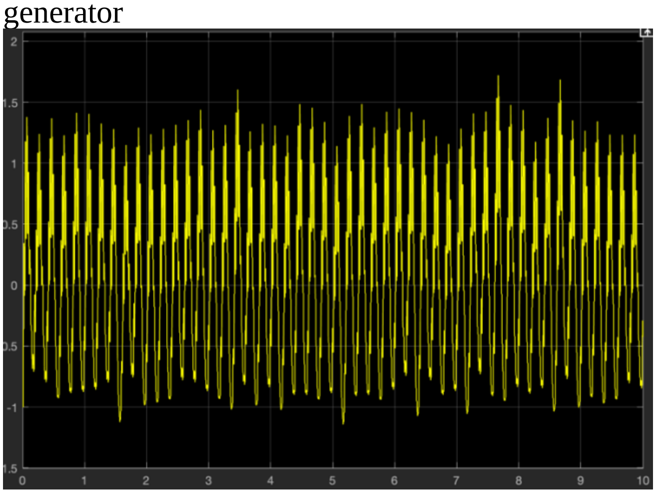


Figure 34: resulting demodulated wave with a noise power of 0.001 for the white noise generator



From the figures above the power of the with white noise is negatively correlated to the fidelity of the resulting signal produced by the demodulator.

Conclusion

The aims of the laboratory were to investigate amplitude modulation and demodulation with a focus on how the methods of these processes affects the resulting signal for information transfer across communication channels. Within this report it was shown that AM waves were successfully generated through modulation and then successfully demodulated. In addition, modulation index and noise's effect on the AM signal generation and demodulation were investigated and corroborated, resulting in a better understanding of their respective interactions. Within the investigation the existence of side frequencies was found and correctly explained. The order of filters in demodulations were shown to affect demodulation quality as well.

References

1. Anon, 2021. *Amplitude Modulation/Superheterodyne*. [online] Fas.org. Available from: https://fas.org/man/dod-101/navy/docs/es310/AM.htm [Accessed 7 May 2021].
2. Laboratory guide
3. Anon, 2021. *http://web.mit.edu/6.02/www/s2012/handouts/14.pdf*. [online] Web.mit.edu. Available from: http://web.mit.edu/6.02/www/s2012/handouts/14.pdf [Accessed 7 May 2021].