**Faculty of Engineering & Technology Electrical & Computer Engineering Department**

**Communication Lab - ENEE4113**

**Experiment 1: Normal Amplitude Modulation and Demodulation**

**Prelab #1**

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**Section**: 4


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# Theoretical Prelab

## Definition Normal Amplitude Modulation (AM)

Is the process of varying the amplitude of a sinusoidal carrier wave in synchronism with, and in direct proportion, to the amplitude of a modulating signal.[1]

### Mathematical Representation of AM

$$s(t) = A_c\big(1 + K_a m(t)\big)\cos(2\Pi f_c t)$$

Where:

- Ac: The amplitude of carrier signal
- fc: The frequency of carrier signal
- m(t): Message signal
- ka: The amplitude sensitivity

AM transmitters vary the amplitude of the carrier wave:

- The amplitude of the carrier wave is proportional to the amplitude of the signal being modulated.[2]
- If the modulation signal frequency increases, the amplitude of the carrier changes at a greater rate.[2]
- If the modulation signal frequency increases, the sidebands move further from the carrier. [2]

## Frequency Spectrum of AM signal

The frequency spectrum of an AM signal can be obtained using Fourier analysis, and it is given by:

$$s(f) = \frac{A_c k_a}{2}[M(f - f_c) + M(f + f_c)] + \frac{Ac}{2}[\delta(f - f_c) + \delta(f + f)]$$

Where:

- M(f) is the Fourier transform of the modulating signal.
- δ (f) is the delta function.

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# Demodulation of an AM Signal

Demodulation is defined as extracting the original information-carrying signal from a modulated carrier wave. A demodulator is an electronic circuit that is mainly used to recover the information content from the modulated carrier wave. [3]

The demodulated signal can be expressed as:

$$m(t) = A_C s(t)\cos(2\Pi f_C t)$$

Which is the product of the received signal and a local oscillator at the carrier frequency. This signal is then passed through a low-pass filter to remove the carrier frequency and obtain the modulating signal.

# Software Prelab

## Message signal

$$m(t) = 0.85\cos(2\pi(1000)t)$$

### Plot Message signal in Time Domine

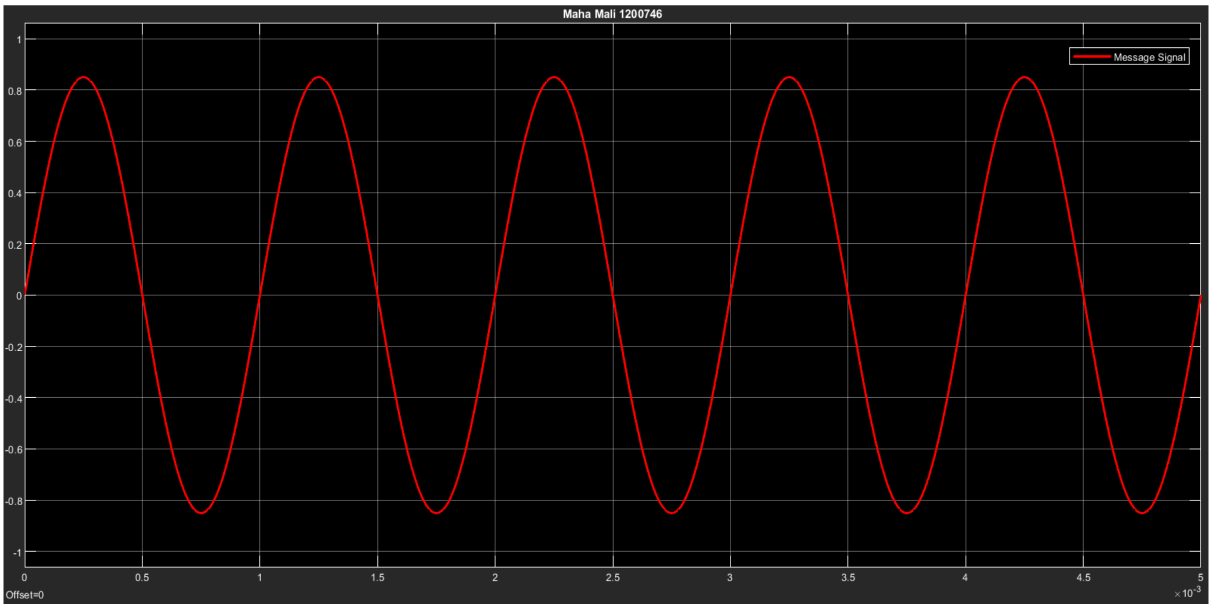


*Figure 1: Message signal in time domain*

We notice from the graph that the amplitude of the Message signal is greater than 0.8, and this is very similar to the amplitude value in the Message signal equation.

### Plot Message signal in Frequency Domine

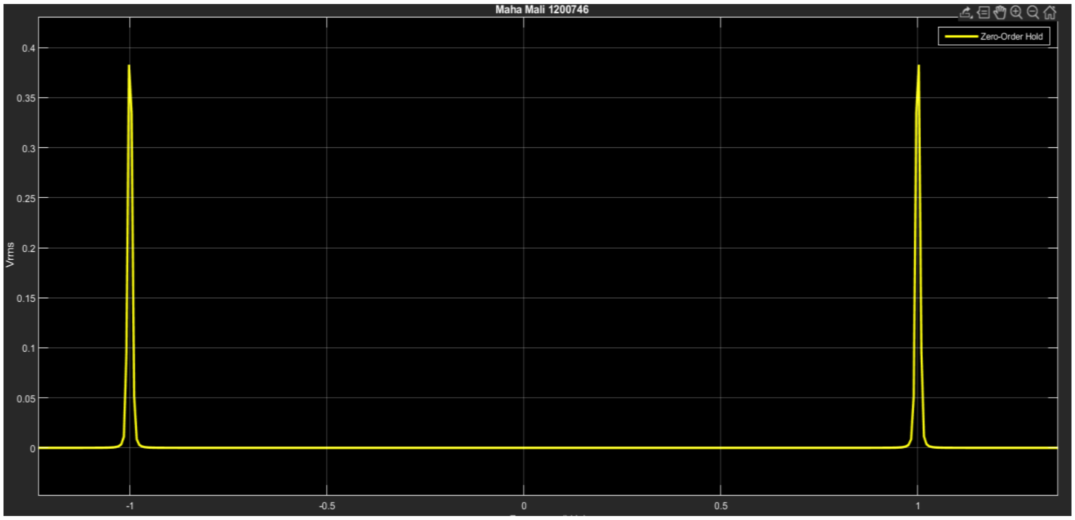


*Figure 2: spectrum of message signal*

From the graph for the spectrum of message signal we notice that there is two delta function one around -1khz, and another one around 1khz.

## Carrier signal

$$c(t) = 1\cos\left(2\pi\,(15000)\,t\right)$$

### Plot Carrier signal in Time Domine

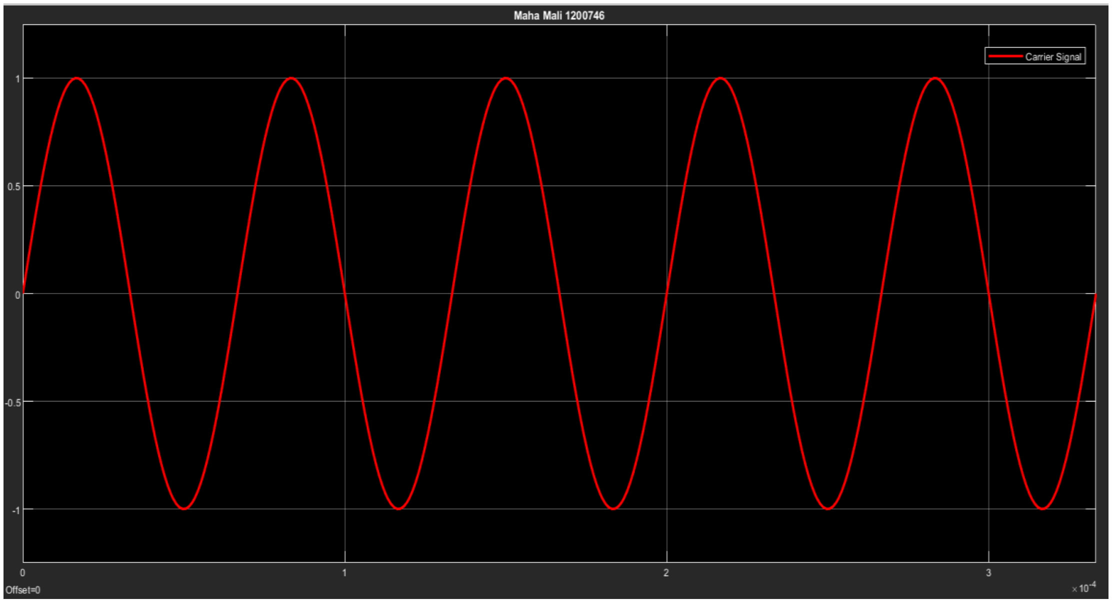


*Figure 3 :carrier signal in time domain*

We notice from the graph that the amplitude of the carrier signal is 1, and this is very similar to the amplitude value in the carrier signal equation.

## Plot Carrier signal in Frequency Domine

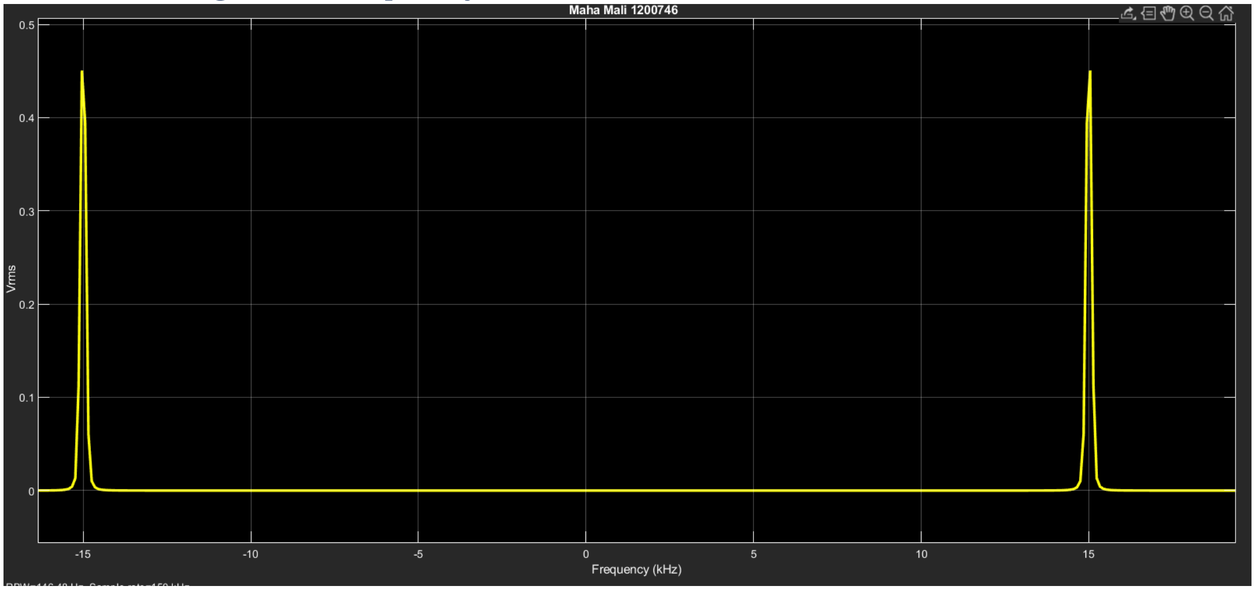


*Figure 4: carrier signal in frequency domain*

From the graph for the spectrum of carrier signal we notice that there is two delta function one around -15khz, and another one around 15khz.

## When (μ=1)

### Calculate the value of $k_a$

$\mu = k_a \cdot A_m$ , given $m(t)$ = 0.85cos ($2\pi$ (1000) $t$) so $A_m$=0.85

ka = (μ) / (Am)

= (1) / (0.85)

= 1.1765

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### Mathematical Representation of AM Signal in Time Domain

Given

- $m(t)$ = 0.85cos ($2\pi$ (1000) $t$)
- $c(t)$ = 1cos ($2\pi$ (15000) $t$)
-

$$s(t) = A_c\big(1 + K_a m(t)\big)\cos(2\Pi f_c t)$$

$$s(t) = (1)(1 + 1.1765\ (0.85\cos(\ 2\Pi(1000)t))\cos(2\Pi(15000)t)$$

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### Mathematical Representation of AM Signal in Frequency Domain

S(f) = (Ac) /2 [ δ (f− fc) + δ (f+ fc)] + ((Ac) (μ) /4) [ δ (f− (fc + fm) + δ (f + (fc + fm))] + ((Ac) (μ) /4) [ δ (f− (fc - fm) + δ (f + (fc - fm))]

= (1) /2 [ δ (f− 15k) + δ (f+ 15k)] + ((1) (1) /4) [ δ (f− (16000) + δ (f + (16000))] + ((1) (1) /4) [ δ (f− (14000) + δ (f + (14000))]

## Build The Diagram When Modulation Index =1 (μ=1) Step by Step

### Modulation

The figure below shows the general block diagram for AM modulation we can build it easily by using mathematical representation of AM signal in time domain

$$s(t) = A_c\big(1 + K_a m(t)\big)\cos(2\Pi f_c t)$$

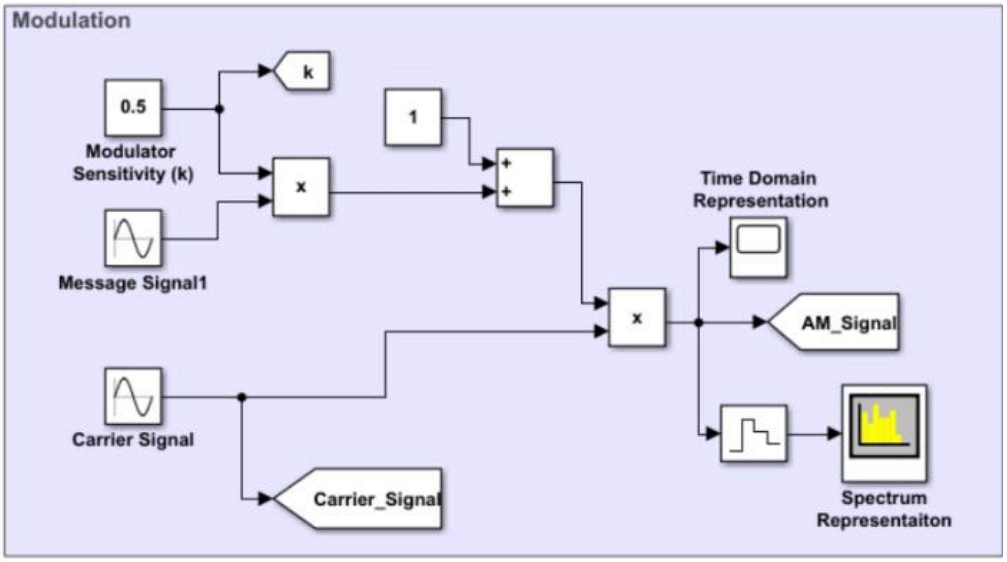



*Figure 5: General Modulation*

The figure shows the modulation block diagram for μ=1 by using MATLAB

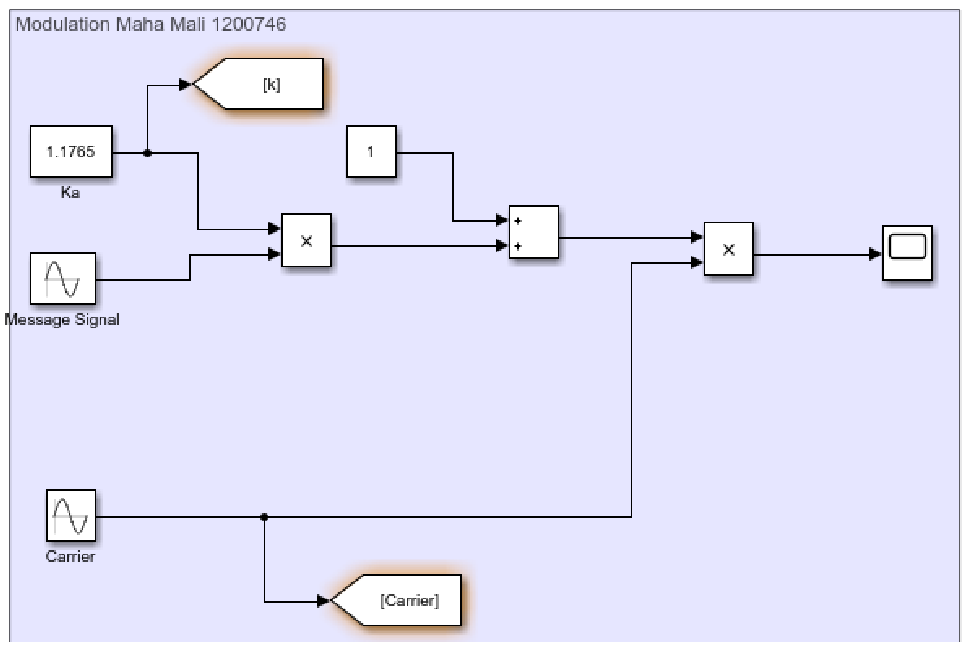



*Figure 6: Modulation Block Diagram for μ=1*

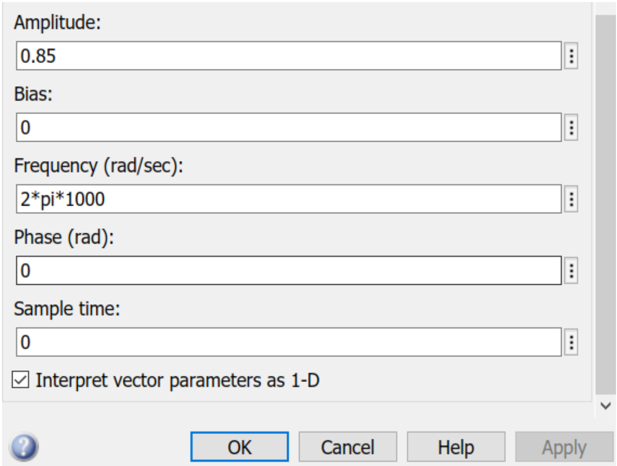



*Figure 7: properties of m(t)*

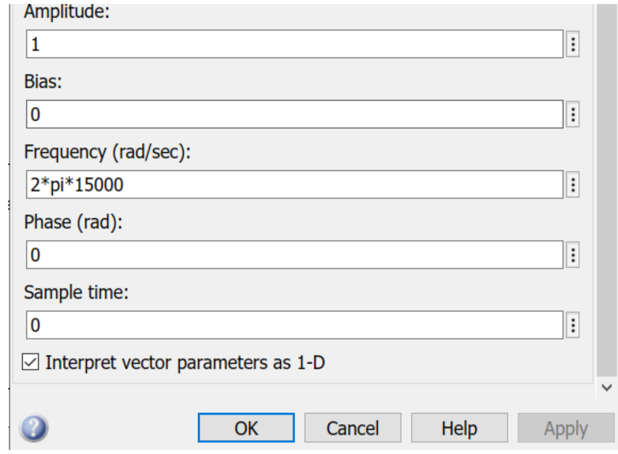



*Figure 8: properties of c(t)*

To plot one cycle of s(t) we calculate the periodic time which is:

- Period time = 1/fm

  = 8/1000 =0.008 s

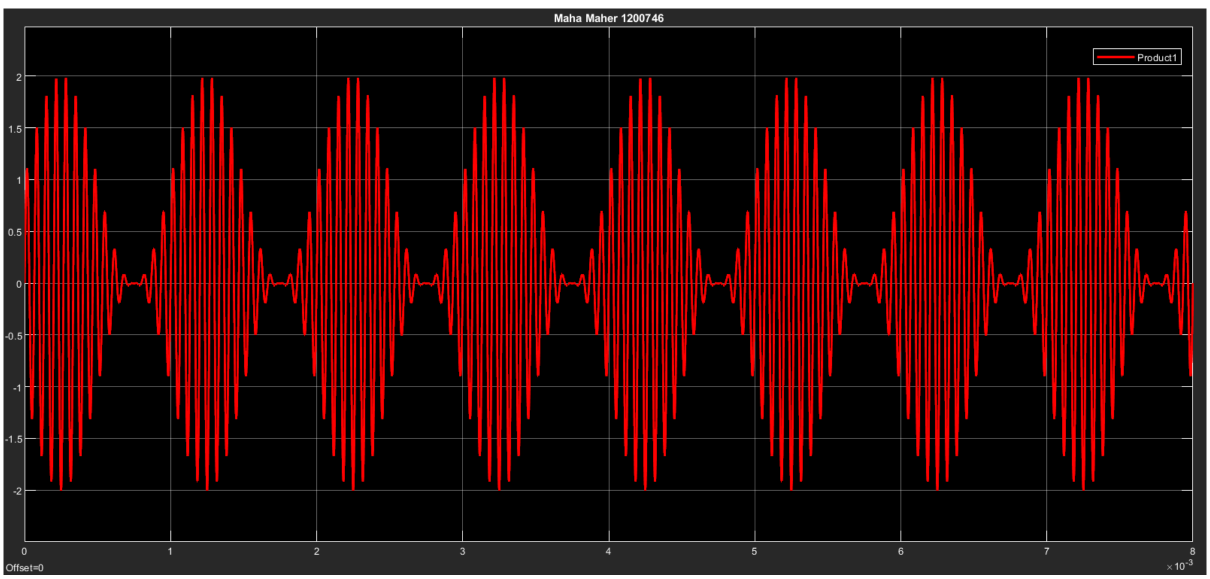



*Figure 9: s(t) in time domain*

Because of u =1 we notice that the type of modulation is normal.

To plot s(f) we add Zero-order hold and Spectrum analyzer

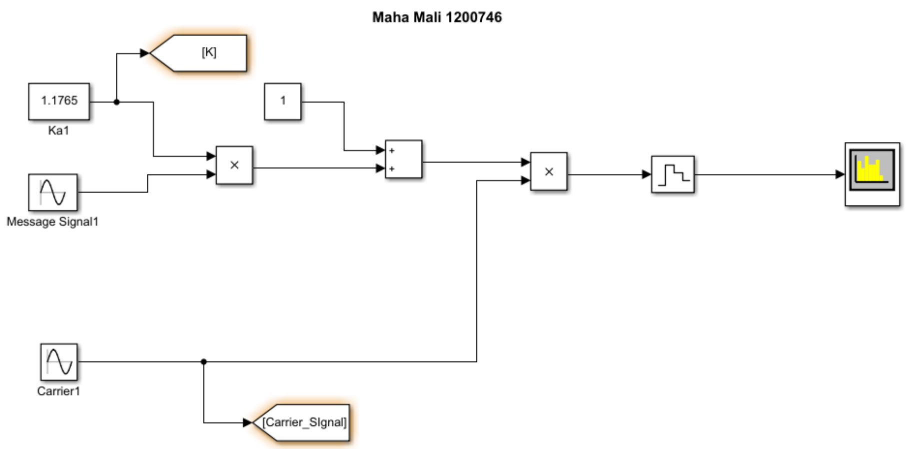



*Figure 10: modulation block with spectrum analyzer*

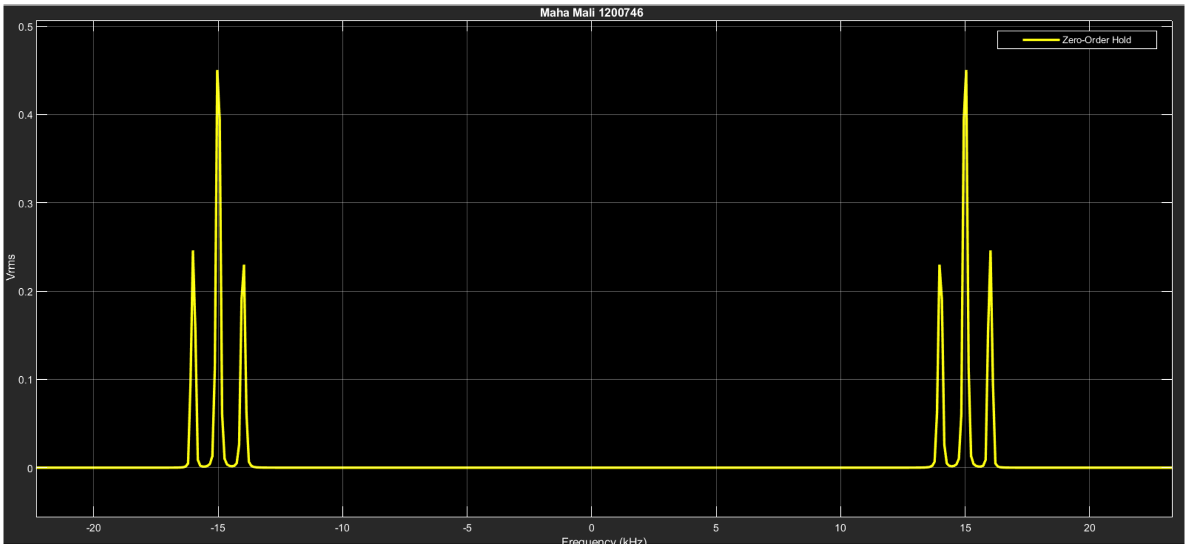



*Figure 11: Spectrum for modulated signal (u=1)*

From the graph of Spectrum, we got almost the same results based on this equation:

$$S(f) = (Ac)/2 [\ \delta (f- fc) + \delta (f+ fc)] + ((Ac)(\mu)/4) [\ \delta (f- (fc + fm) + \delta (f + (fc + fm))] + ((Ac)(\mu)/4) [\ \delta (f- (fc - fm) + \delta (f + (fc - fm))]$$

$$= (1)/2 [\ \delta (f- 15k) + \delta (f+ 15k)] + ((1)(1)/4) [\ \delta (f- (16000) + \delta (f + (16000))] + ((1)(1)/4) [\ \delta (f- (14000) + \delta (f + (14000))]$$

## Demodulation

### Coherent demodulation

The figure below shows the general block diagram for AM Coherent demodulation we can build it easily by using this formula:

$$s(t)_{de} = c(t) * s(t)$$

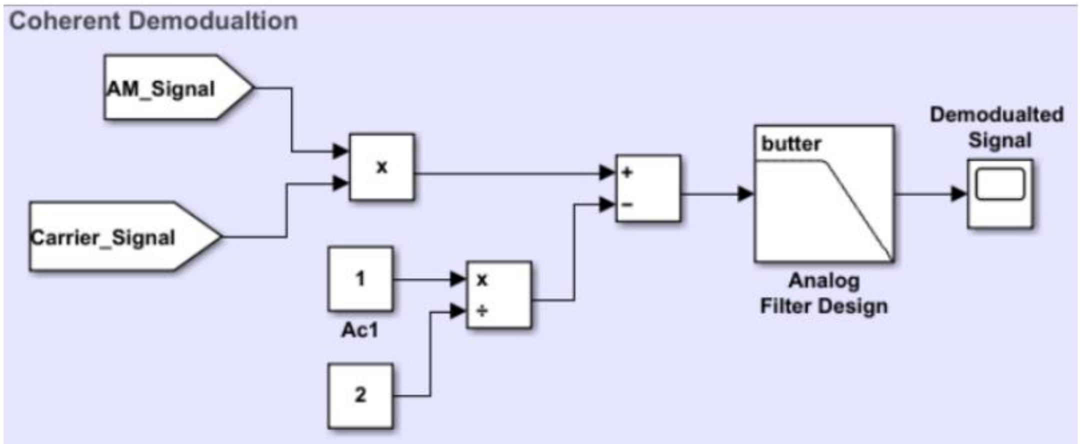



*Figure 12: General Coherent Demodulation*

s(t)de = (cos (2pi (15 k) t)) (cos (2pi (15 k) t) + 0.5 cos (2pi (16k) t) + 0.5 cos (2pi (14k) t))

= 0.5 cos (2pi (30k) t) + 0.5 cos (0) + 0.25 cos (2pi (31k) t) + 0.25 cos (2pi (1k) t) + 0.25 cos (2pi (29k) t) + 0.25 cos (2pi (1k) t)

The figure 13 shows the build of modulation block diagram for μ=1 by using MATLAB:

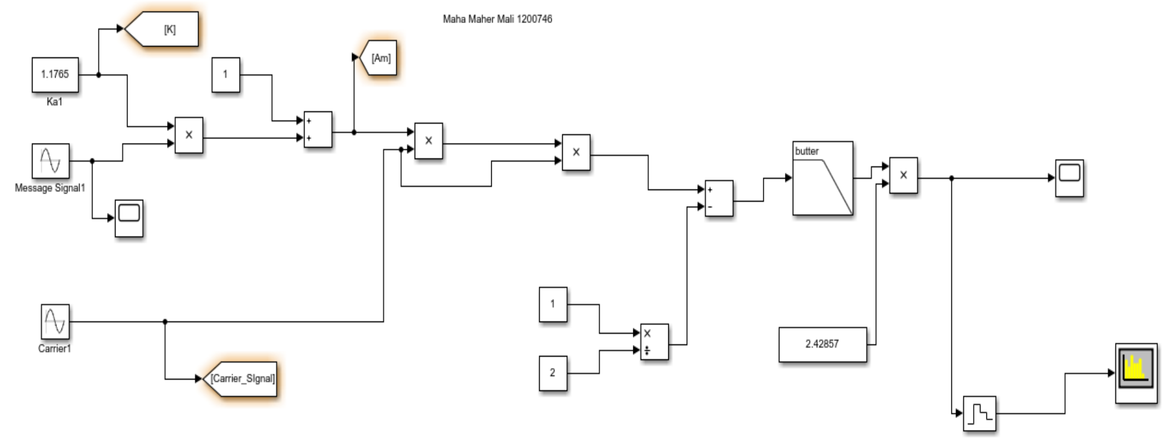



*Figure 13: Demodulation Block Diagram for μ=1*

Due to the difficulty in controlling the gain value of the filter, the filter output was multiplied by a factor of 2.429 to obtain the signal amplitude that corresponds to the original amplitude of 0.85.

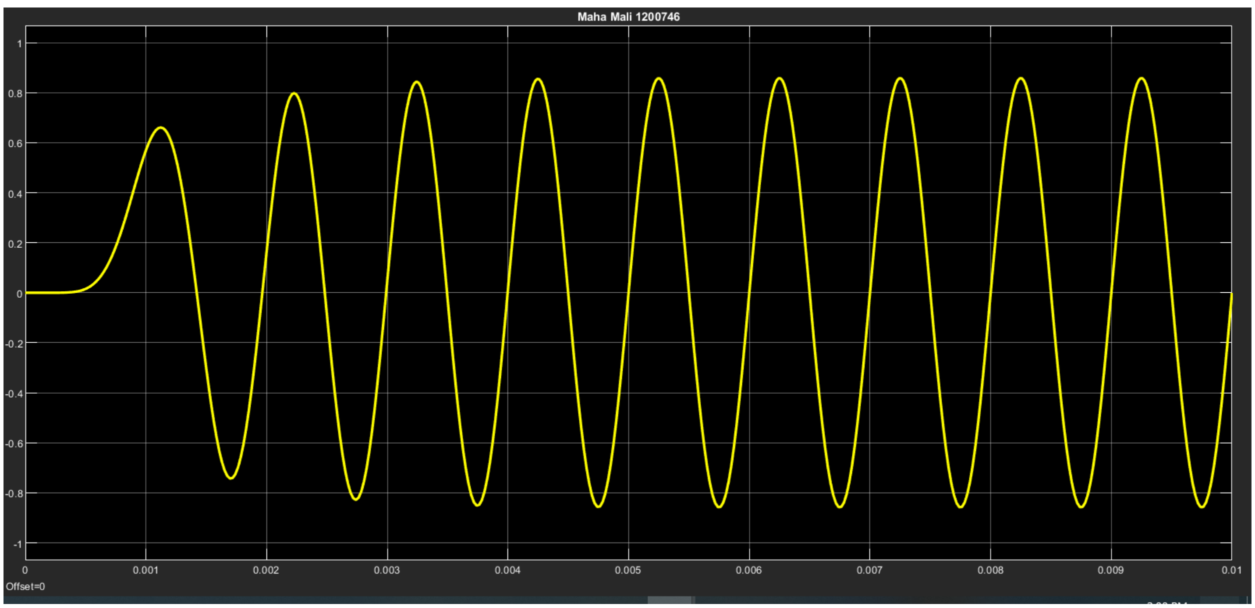



*Figure 14: coherent demodulation output in time domain*

As we see in the figure below, the output of the demodulation process is equal to the message signal. that's mean that we got the message signal after demodulation.

m(t) = 0.85 (2 pi (1000) t)

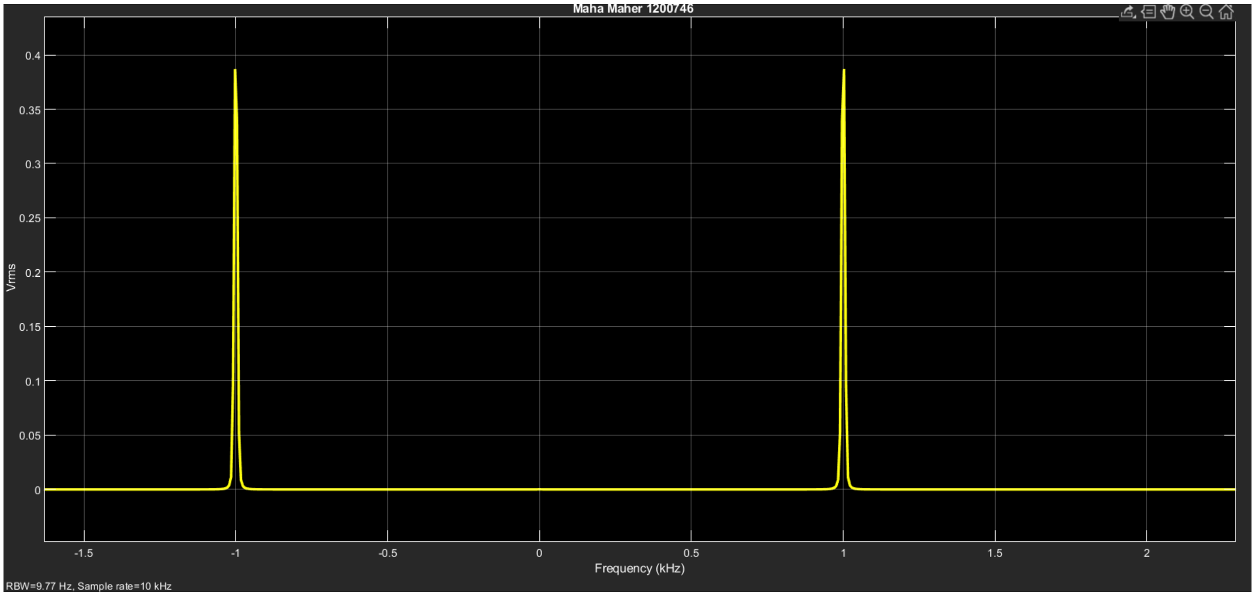



*Figure 15: coherent demodulation output in frequency domain*

## Envelope detector demodulation

The figure below shows the general block diagram for AM Envelope detector demodulation

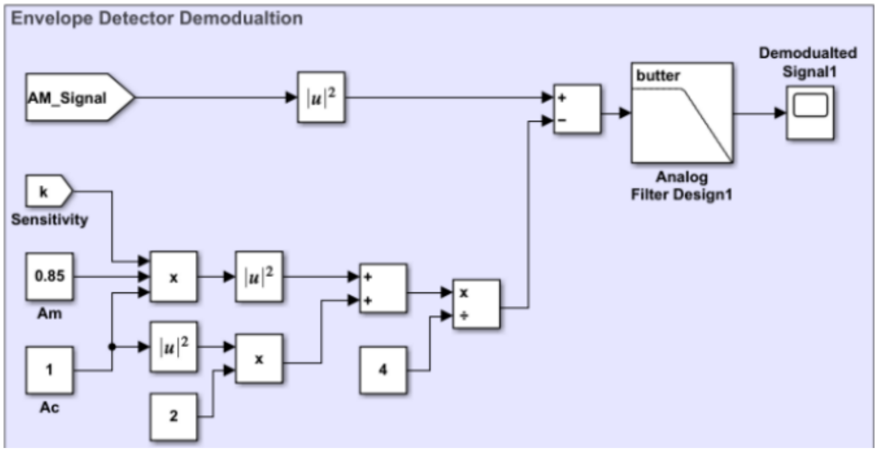
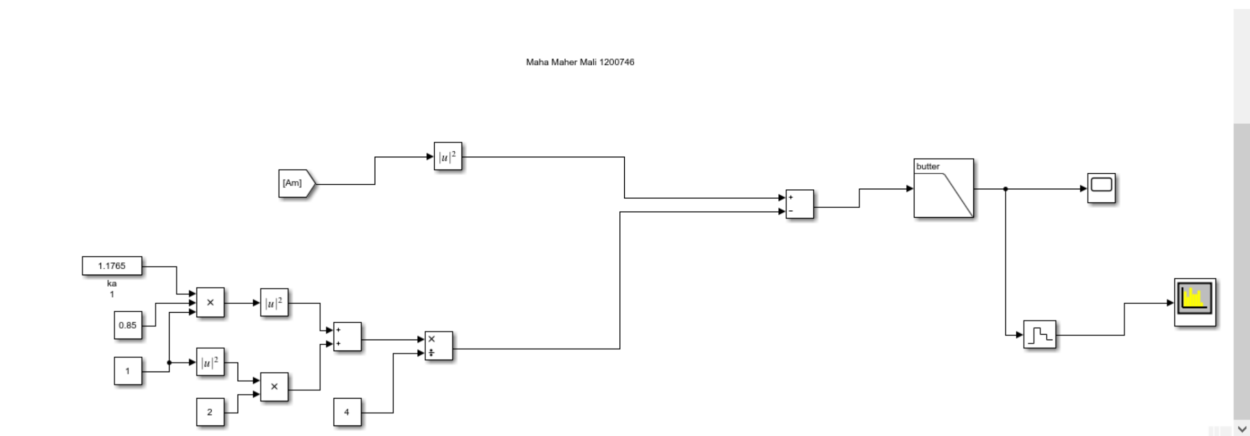



*Figure 16: Envelope detector demodulation general formula*

now we should build the modulation block diagram for μ=1 by using MATLAB:



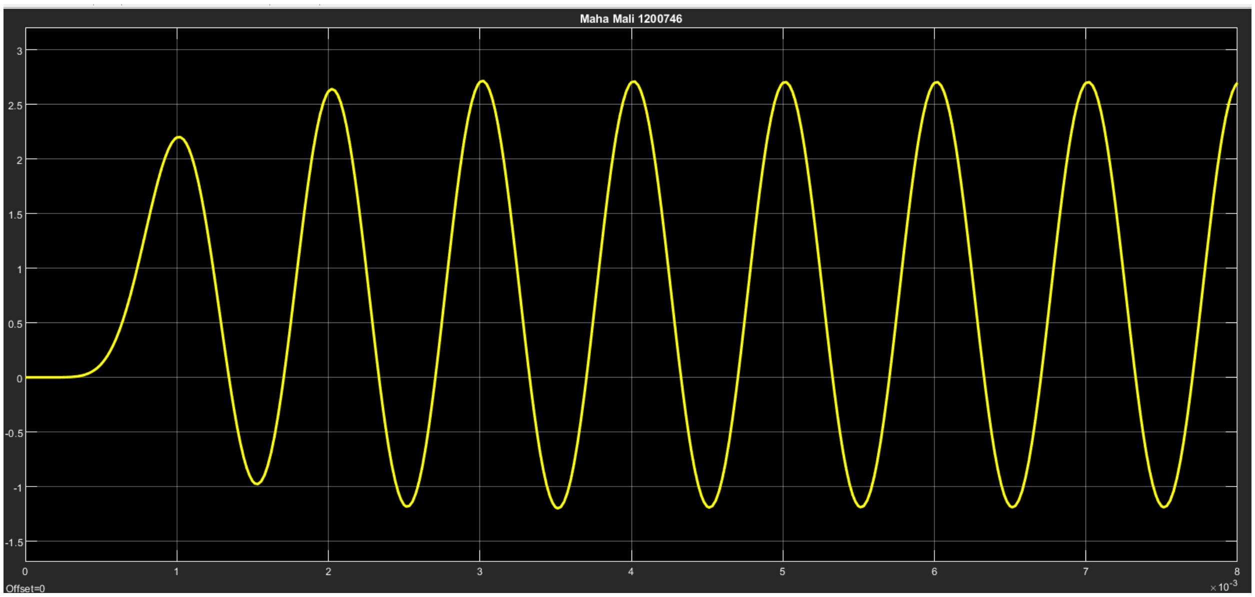



*Figure 17: Envelope detector demodulation output in time domain*

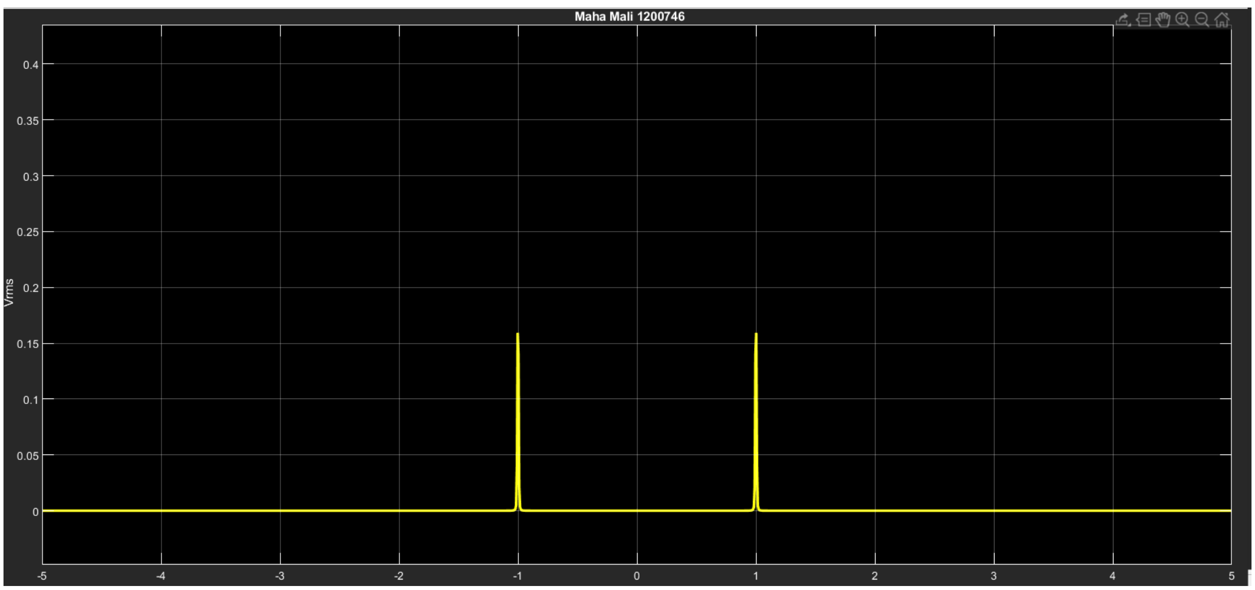



*Figure 18: Envelope detector demodulation output in frequency domain*

## When (μ=0.5)

### Calculate the value of $k_a$

$\mu = k_a \cdot A_m$ , given $m(t)$ = 0.85cos (2$\pi$ (1000) $t$) so $A_m$=0.85

ka = (μ) / (Am)

= (0.5) / (0.85)

= 0.588

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### Mathematical Representation of AM Signal in Time Domain

Given

- $m(t)$ = 0.85cos (2$\pi$ (1000) $t$)
- $c(t)$ = 1cos (2$\pi$ (15000) $t$)
-

$$s(t) = A_c(1 + K_a m(t))\cos(2\Pi f_c t)$$

$$s(t) = (1)(1 + 0.588\ (0.85 \cos(\ 2\Pi(1000)t))\cos(2\Pi(15000)t)$$

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### Build The Diagram When Modulation Index =0.5 (μ=0.5) Step by Step

#### Modulation

The figure shows the modulation block diagram for μ=0.5 by using MATLAB

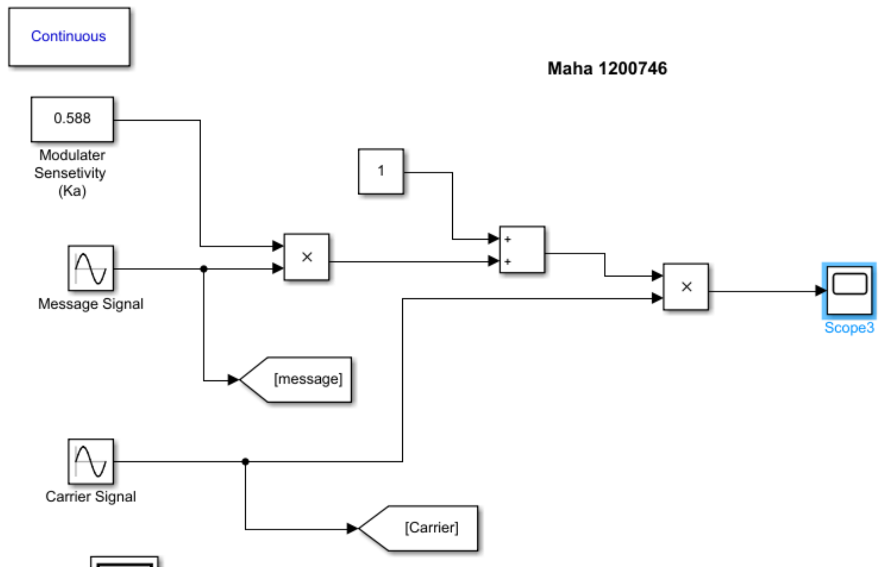


*Figure 19: block diagram for case 2 (u=0.5)*

To plot five cycle of s(t) we calculate the periodic time which is:

- Period time = 1/fm

  = 5/1000

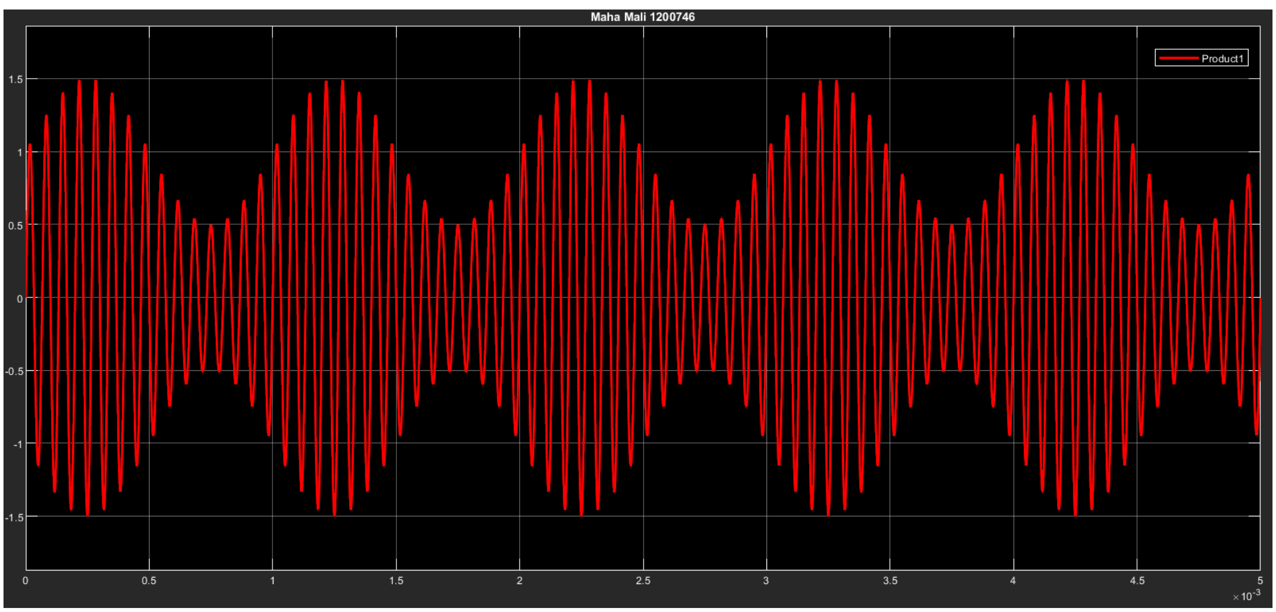


*Figure 20: s(t) in time domine*

Because of μ=0.5we notice that the type of modulation is under modulation.

To plot s(f) we add Zero-order hold and Spectrum analyzer

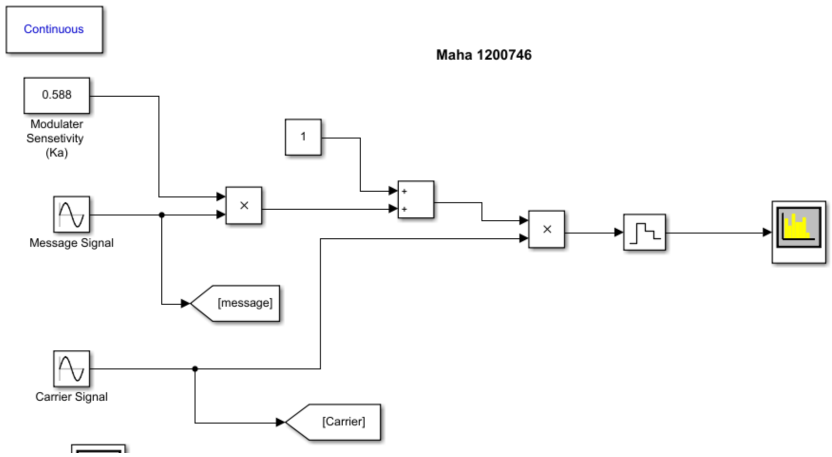


*Figure 21: diagram to plot spectrum*

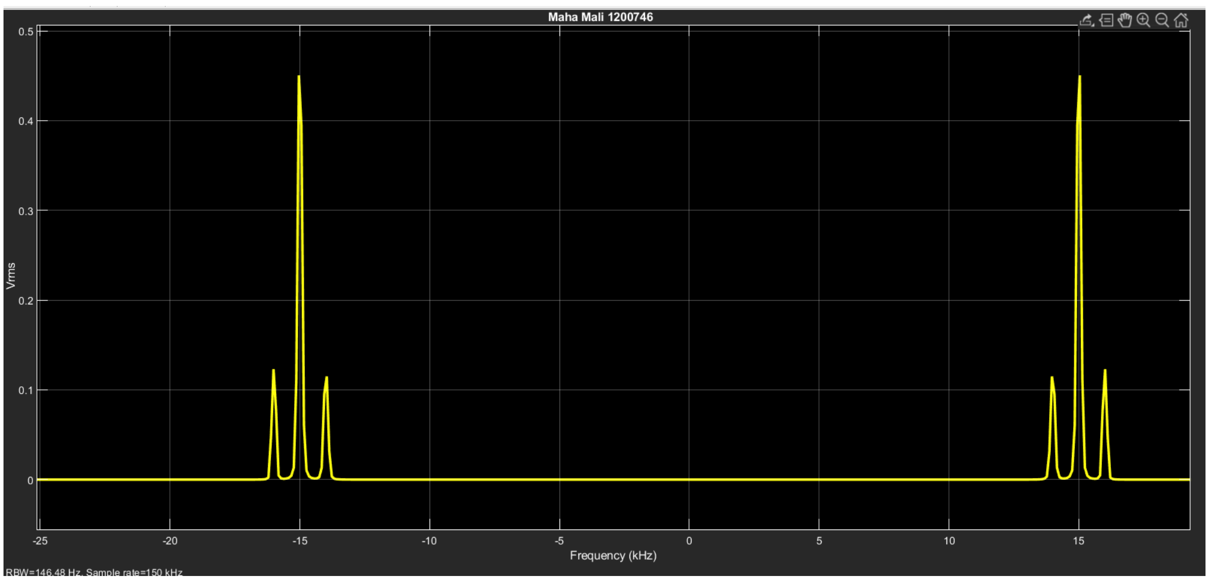


*Figure 22: Spectrum for modulated signal (u=0.5)*

## Demodulation
## Coherent demodulation

The figure shows the build of modulation block diagram for μ=1 by using MATLAB:

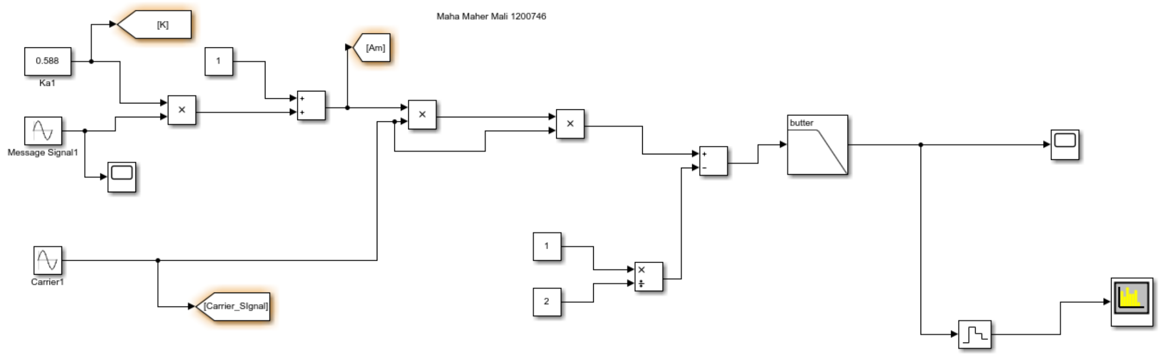


*Figure 23: Coherent demodulation block diagram*

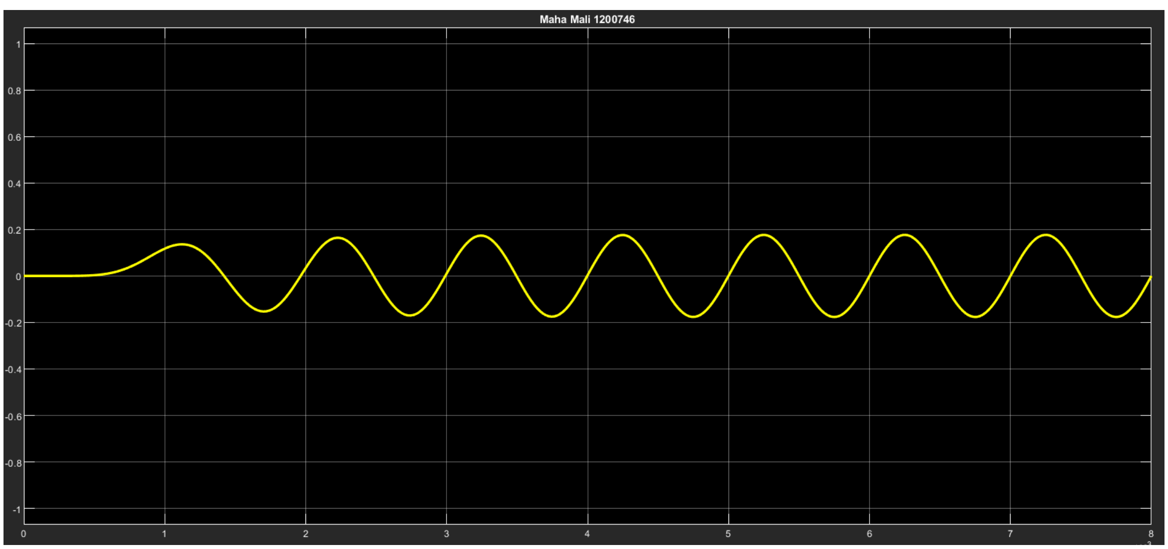


*Figure 24: Coherent demodulation in time domine*

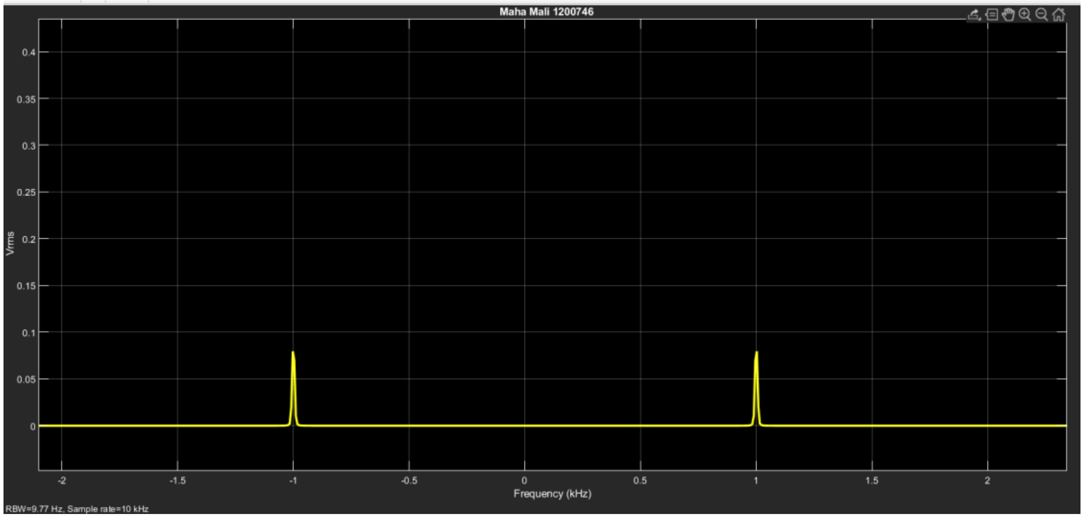


*Figure 25: Coherent demodulation in frequency domine*

## Envelope detector demodulation

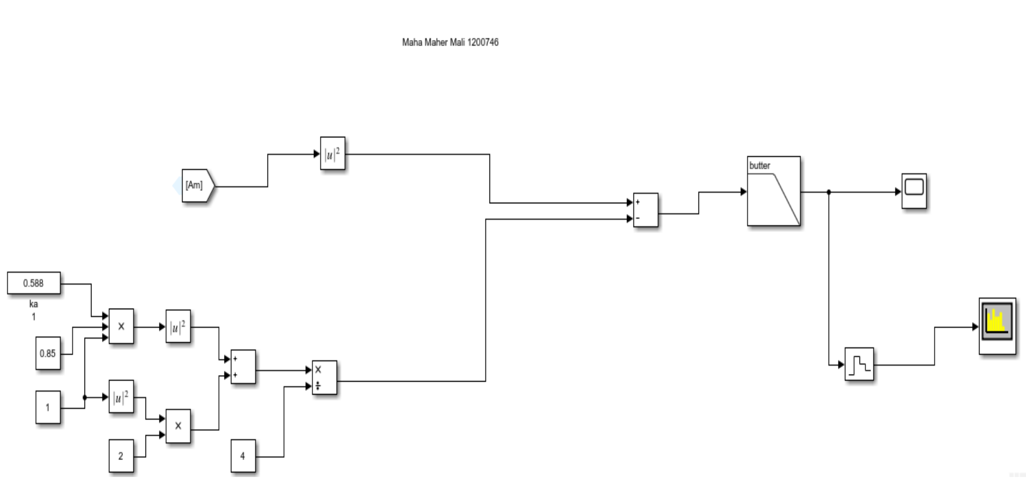


*Figure 26: Envelope detector demodulation block digram when (u=0.5)*

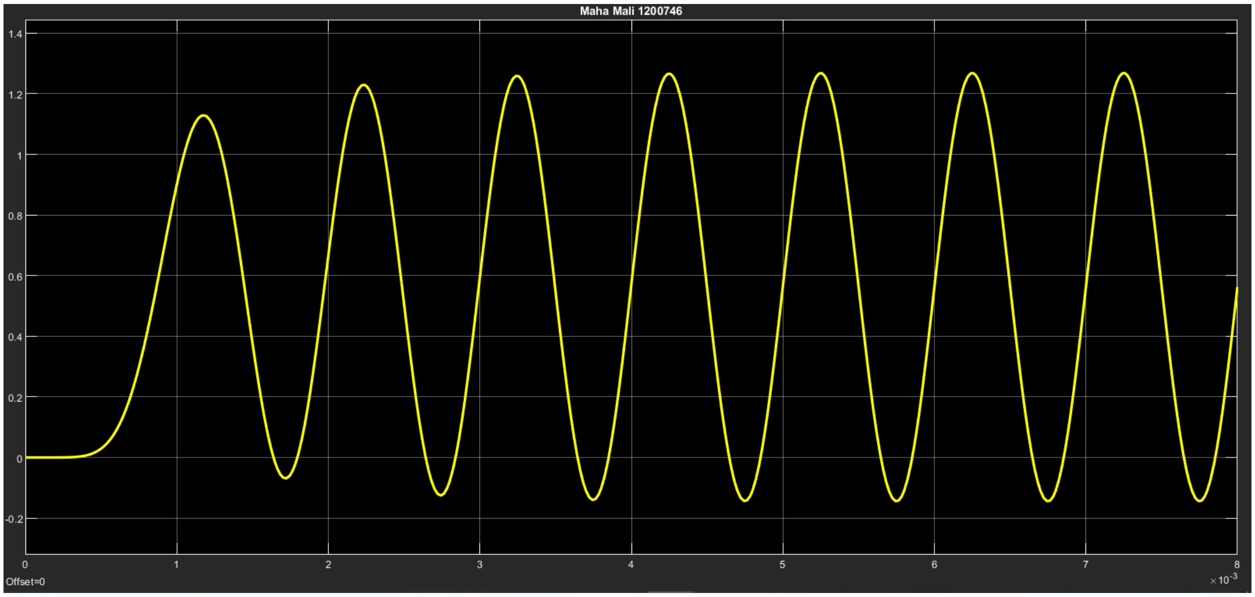


*Figure 27: Envelope detector demodulation in time domine*

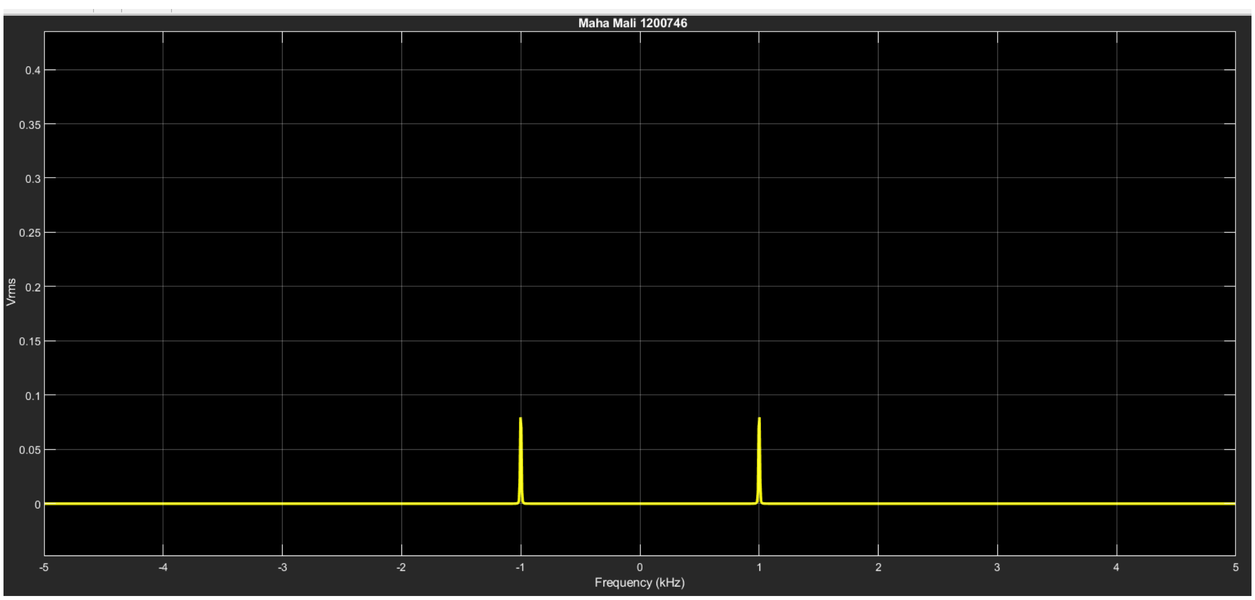


*Figure 28: Envelope detector demodulation in freqancy domine*

## When (μ=1.5)

### Calculate the value of $k_a$

$\mu = k_a \cdot A_m$ , given $m(t)$ = 0.85cos (2$\pi$ (1000) $t$) so $A_m$=0.85

ka = (μ) / (Am)

= (1.5) / (0.85)

= 1.765

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### Mathematical Representation of AM Signal in Time Domain

Given

- $m(t)$ = 0.85cos (2$\pi$ (1000) $t$)
- $c(t)$ = 1cos (2$\pi$ (15000) $t$)

$$s(t) = A_c\big(1 + K_a m(t)\big)\cos(2\Pi f_c t)$$

$$s(t) = (1)(1 + 0.588\ (1.765 \cos\ (\ 2\Pi(1000)t))\cos(2\Pi(15000)t)$$

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## Build The Diagram When Modulation Index =0.5 (μ=0.5) Step by Step

### Modulation

The figure shows the modulation block diagram for μ=1.5 by using MATLAB

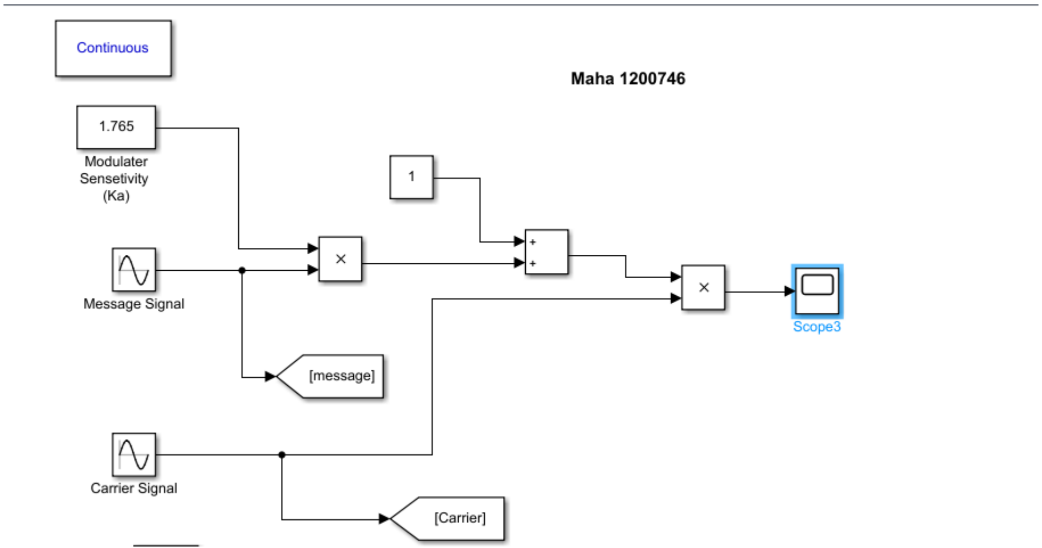



*Figure 29: Block diagram for μ=1.5*

To plot five cycle of s(t) we calculate the periodic time which is:

- Period time = 1/fm

  = 5/1000

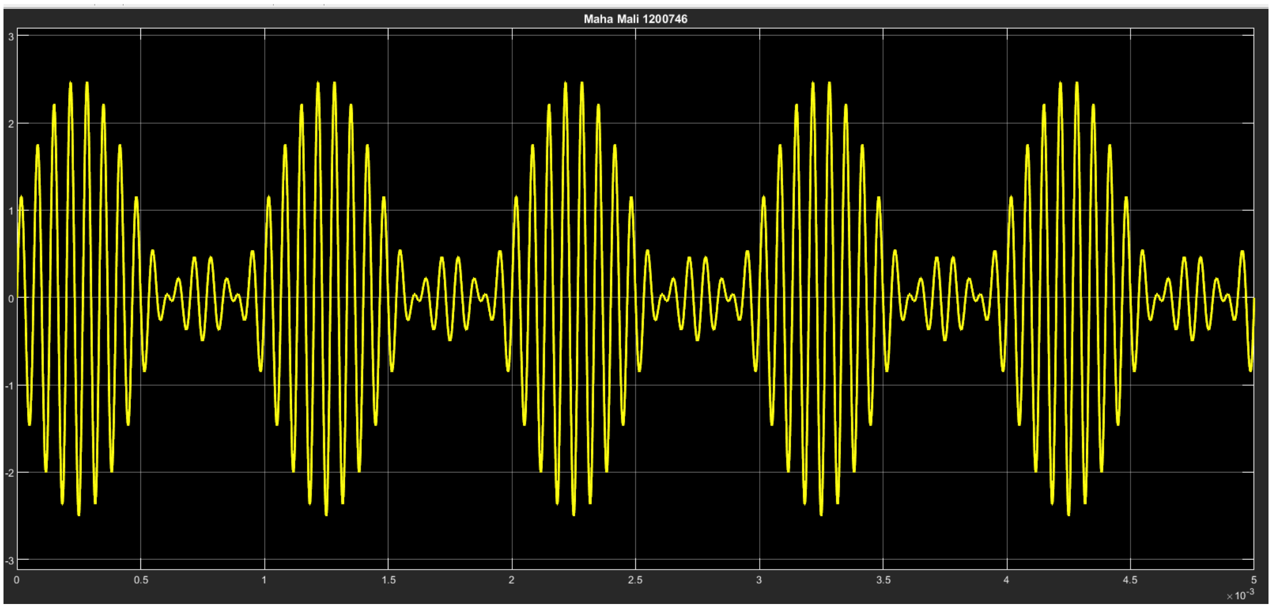
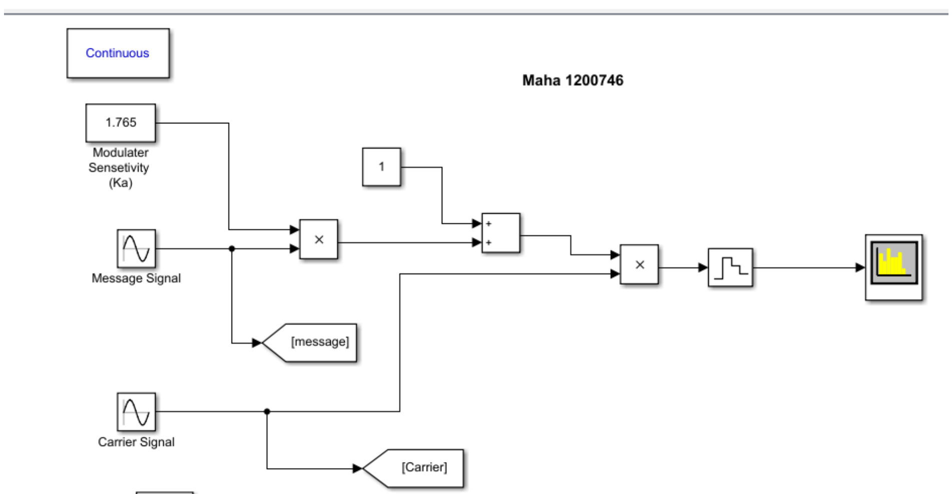



*Figure 30 :s(t) in time domine*

Because of μ=1.5we notice that the type of modulation is over modulation.

To plot s(f) we add Zero-order hold and Spectrum analyzer



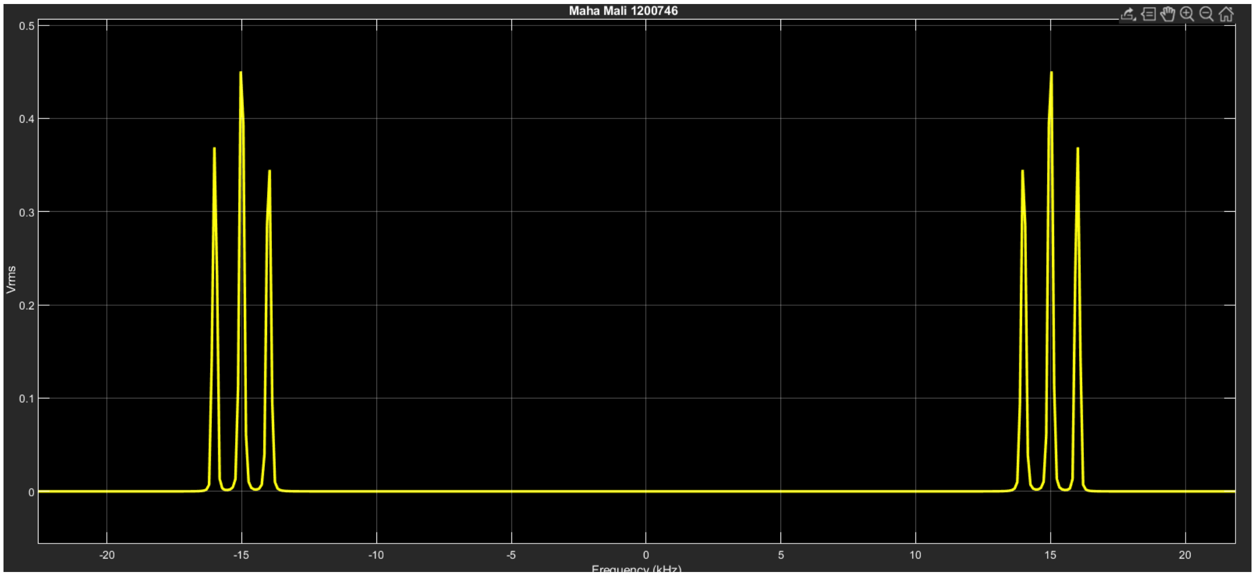



*Figure 31:s(f) in frequency domine*

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## Demodulation

## Coherent demodulation

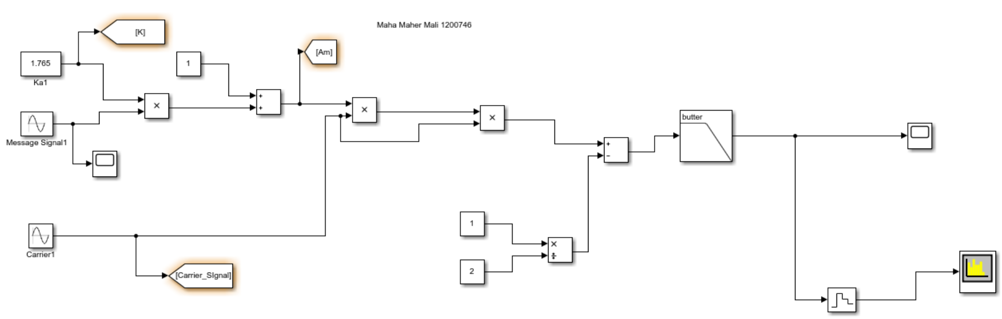


*Figure 32: Coherent demodulation block digram*

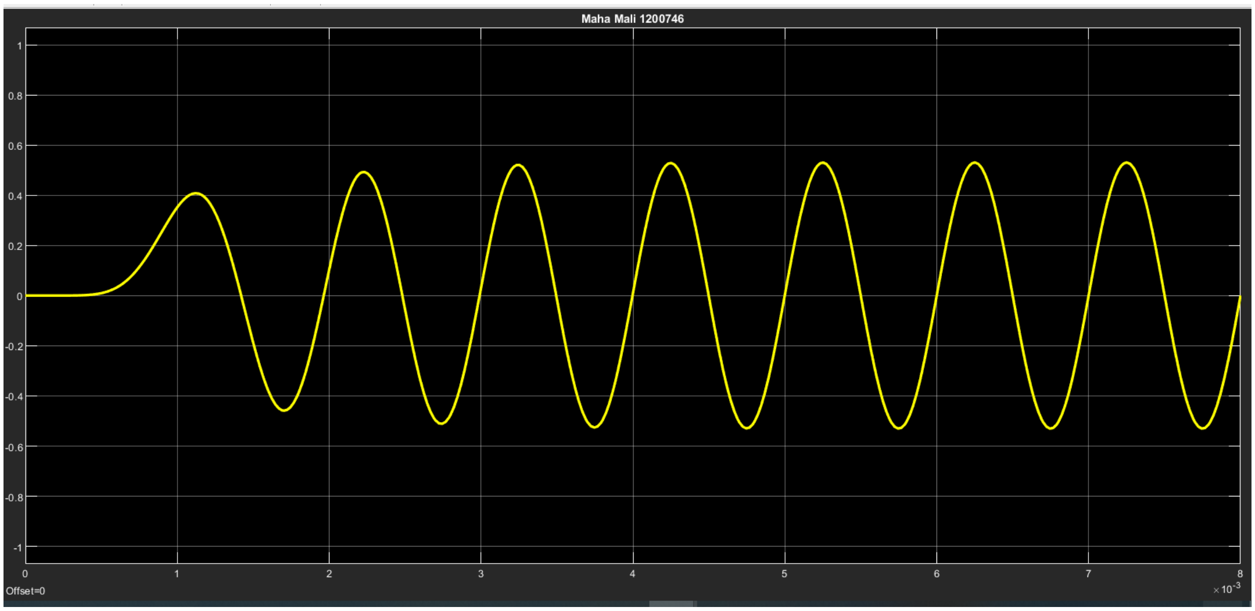


*Figure 33: s(t) in time domine*

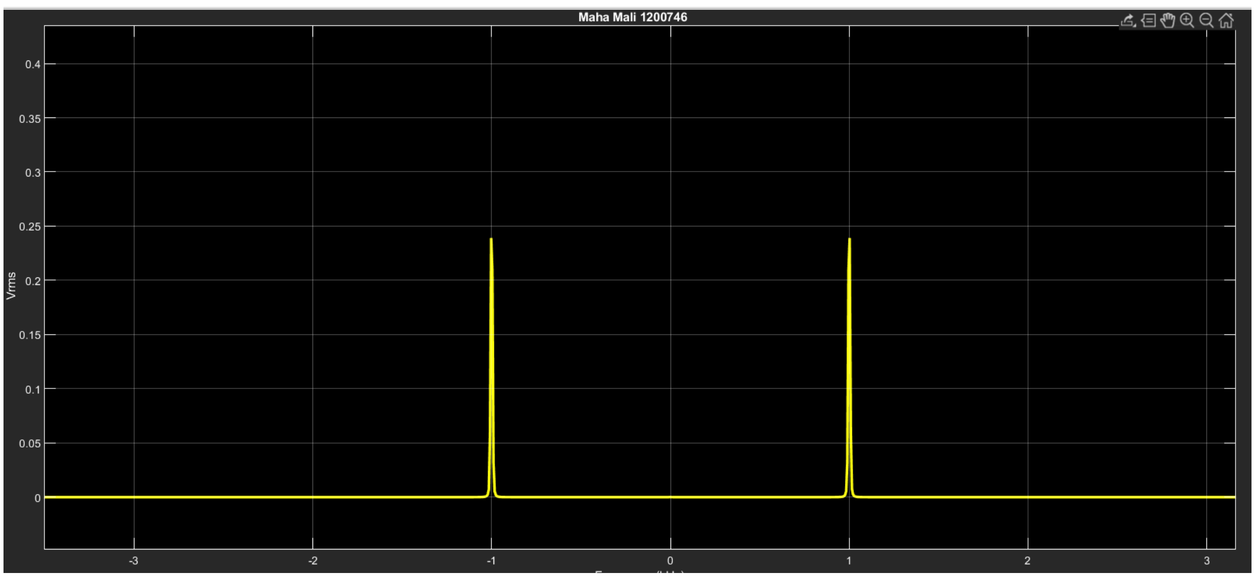


*Figure 34: s(F) in frequency domine*

## Envelope detector demodulation

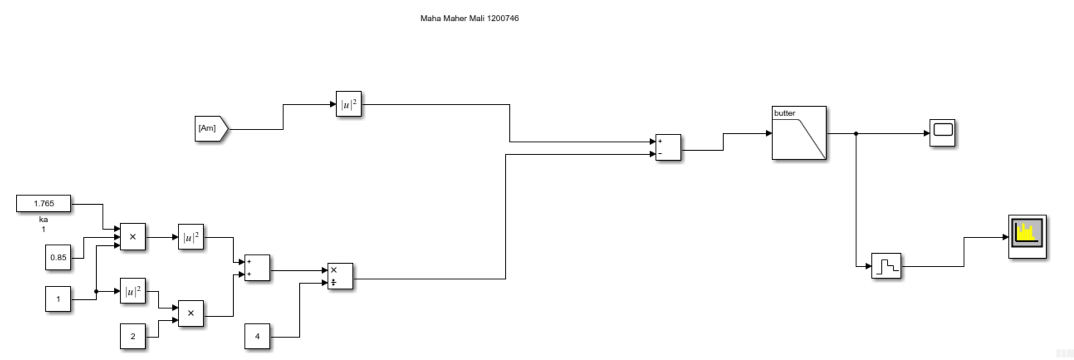


*Figure 35: Envelope detector demodulation*

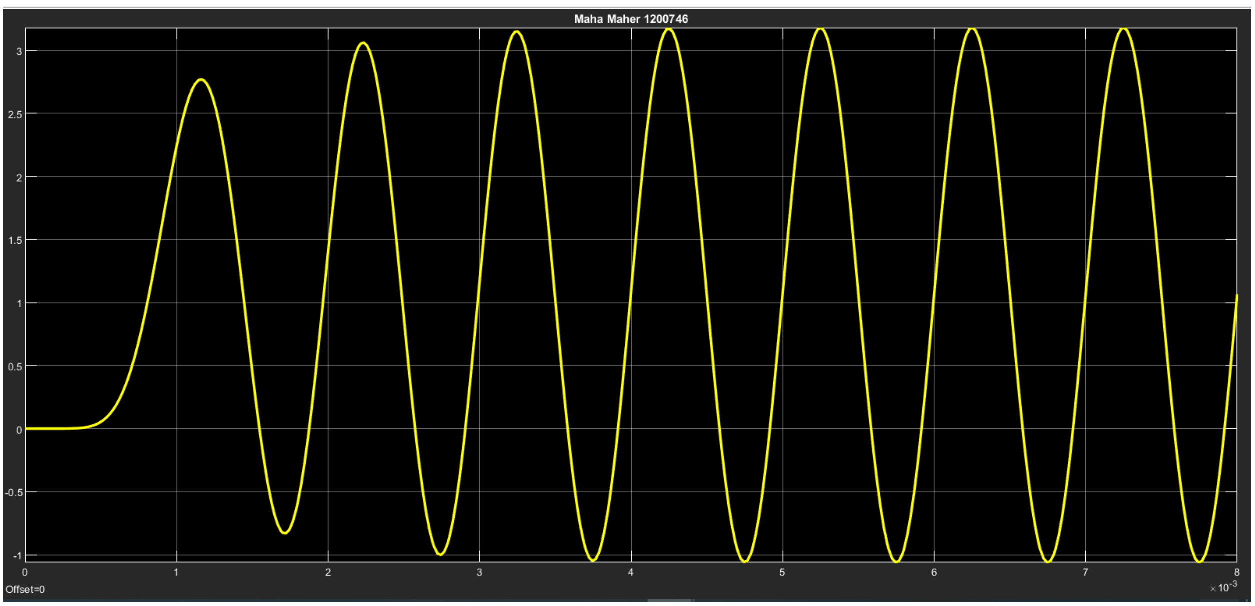


*Figure 36: s(t) in time domine*

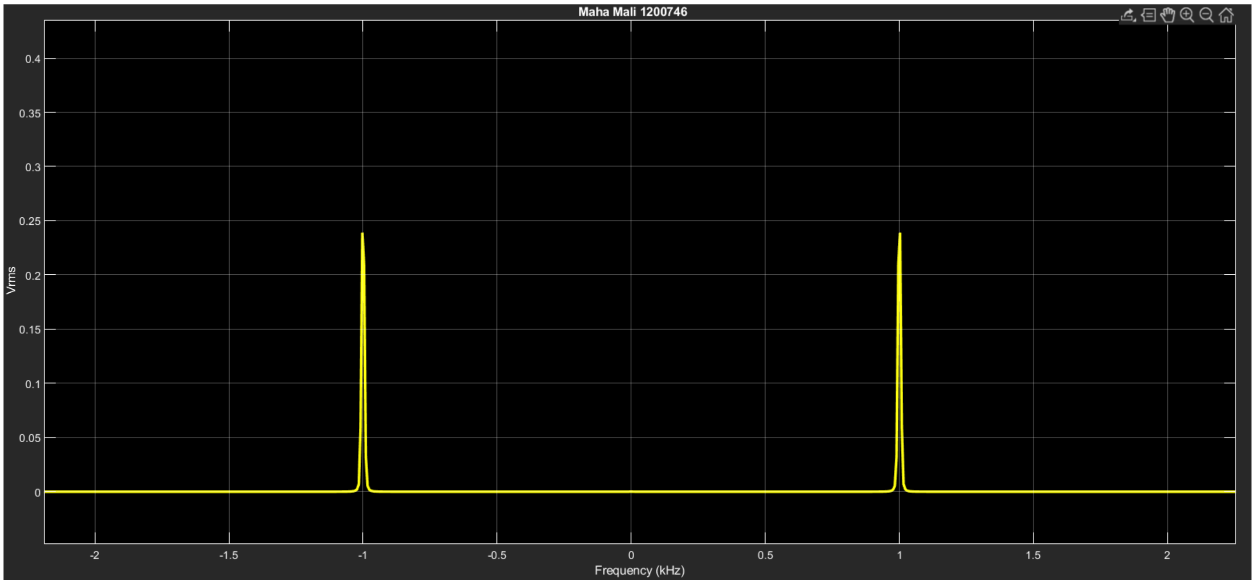


*Figure 37: s(f) in frequency domine*

## References

[1] https://uotechnology.edu.iq/dep/coe/lectures/Analog%20Communication%20%20Systems%20I-pdf/3.%20Amplitude%20Modulation%20Systems.pdf

[2] https://reviseomatic.org/help/2-modulation/Amplitude%20Modulation.php

[3] https://byjus.com/physics/modulation-and-demodulation/