جامعة بيرزيت

BIRZEIT UNIVERSITY

Faculty of Engineering & Technology Electrical & Computer Engineering Department

Communication Lab - ENEE4113

Experiment 4: Frequency Modulation

Prelab #3

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Section: 4

Date: 7-8-2023

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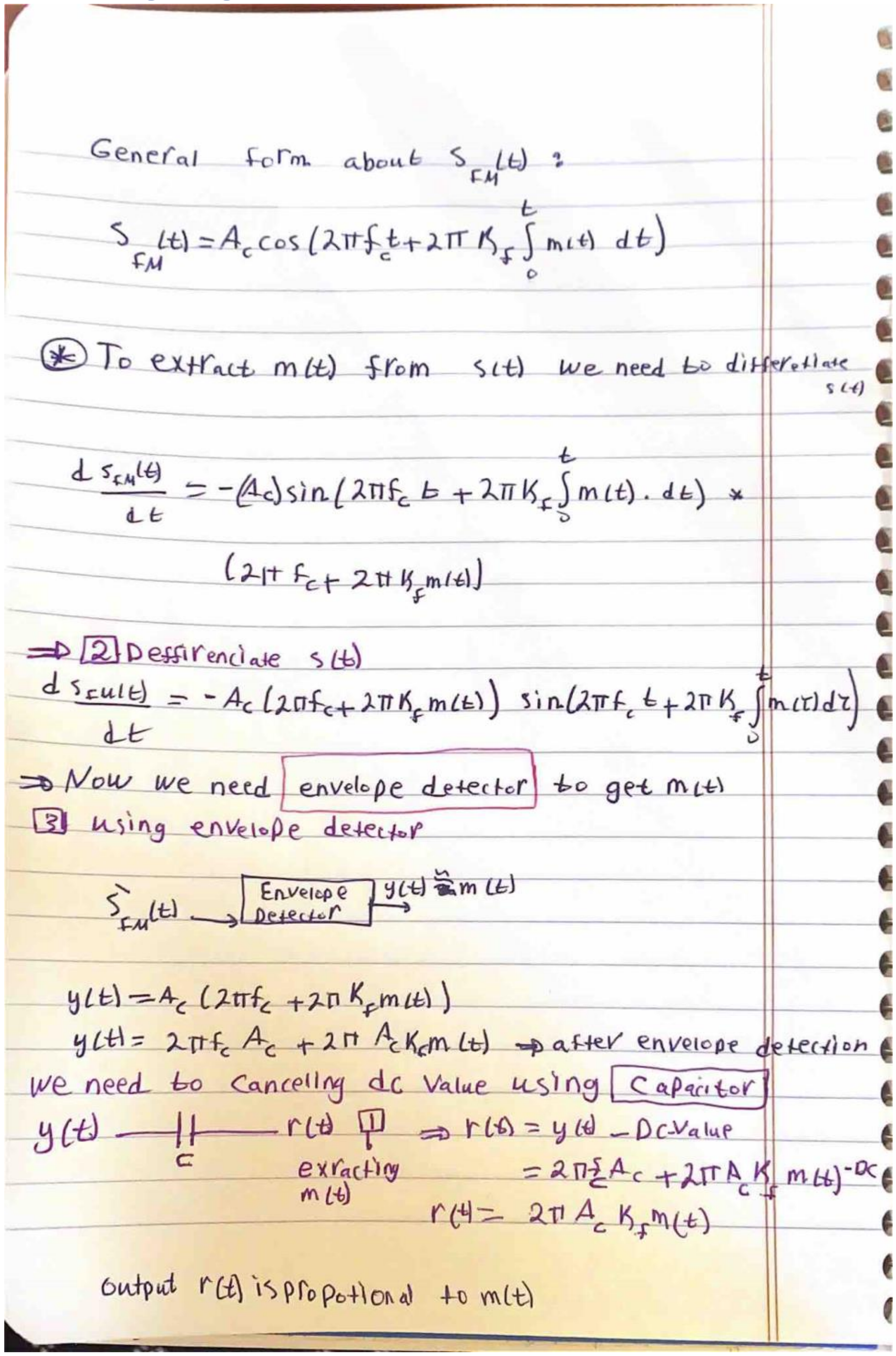
Software Prelab (Simulink MATLAB)

Extract the message signal m(t) from s(t)



General form about $S_{FM}(t)$:

$$S_{FM}(t) = A_c \cos\left(2\pi f_c t + 2\pi K_f \int_0^t m(t)\, dt\right)$$

(*) To extract m(t) from s(t) we need to differentiate s(t)

$$\frac{d\, s_{FM}(t)}{dt} = -(A_c) \sin\left(2\pi f_c t + 2\pi K_f \int_0^t m(t) \cdot dt\right) * (2\pi f_c + 2\pi K_f m(t))$$

⇒ $\boxed{2}$ Dessirenciate s(t)

$$\frac{d\, s_{FM}(t)}{dt} = -A_c (2\pi f_c + 2\pi K_f m(t)) \sin\left(2\pi f_c t + 2\pi K_f \int_0^t m(\tau) d\tau\right)$$

⇒ Now we need $\boxed{\text{envelope detector}}$ to get m(t)

$\boxed{3}$ using envelope detector

$\acute{S}_{FM}(t) \longrightarrow$ Envelope Detector $\xrightarrow{y(t) \approx m(t)}$

$$y(t) = A_c (2\pi f_c + 2\pi K_f m(t))$$

$$y(t) = 2\pi f_c A_c + 2\pi A_c K_f m(t)$$ ⇒ after envelope detection

we need to cancelling dc value using $\boxed{\text{Capacitor}}$

$y(t)$ —||— $r(t)$ $\boxed{1}$ extracting m(t) ⇒ $r(t) = y(t) - DC\,Value$

$$= 2\pi f_c A_c + 2\pi A_c K_f m(t) - DC$$

$$r(t) = 2\pi A_c K_f m(t)$$

output r(t) is proportional to m(t)

Figure 1:Stepes to Extract the message signal m(t) from s(t)

The figure shows the calculation to find the message signal:

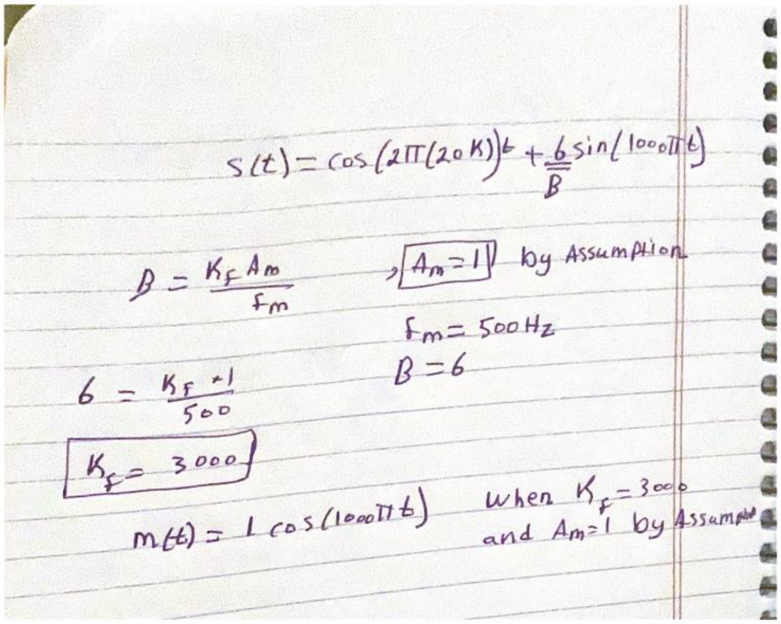


Figure 2:Message Signal

Plot 5 cycle from Message signal m(t) and s(t)

Block Diagram

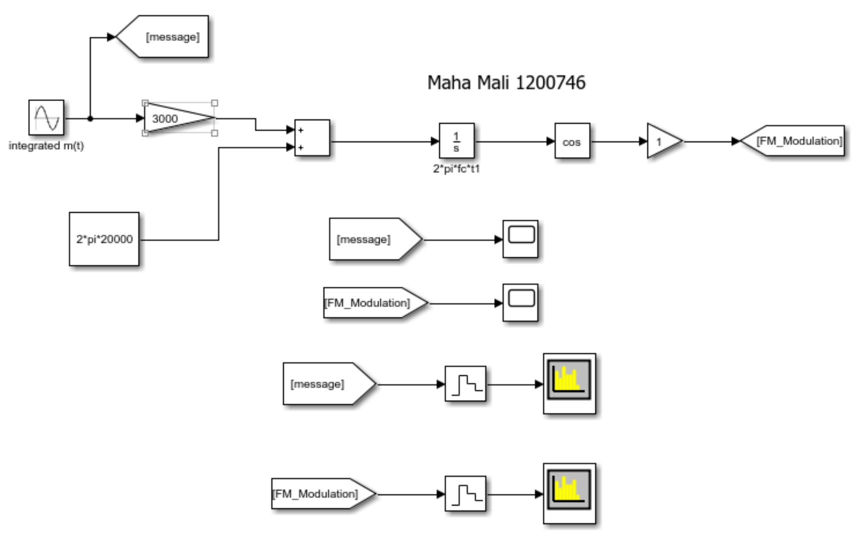


Figure 3: FM Modulation Block Diagram

Message Signal

Time Domine

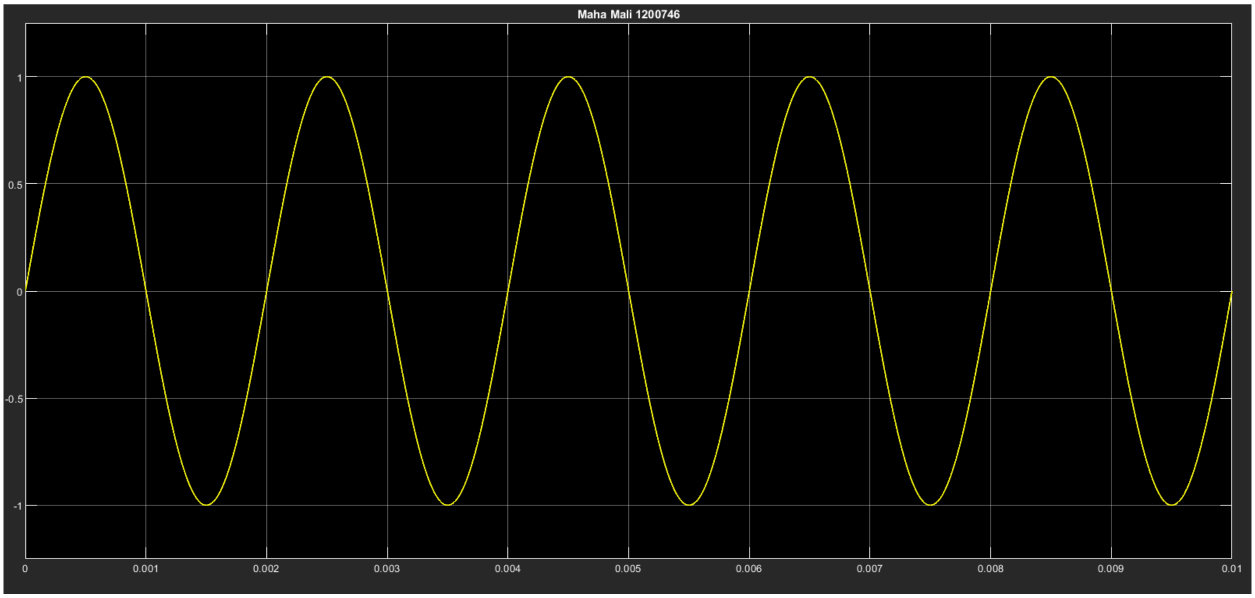


Figure 4: Message Signal in Time domine

From this graph we notice that we got the m(t) that we calculate it by hand with amplitude 1 .

Frequency Domine

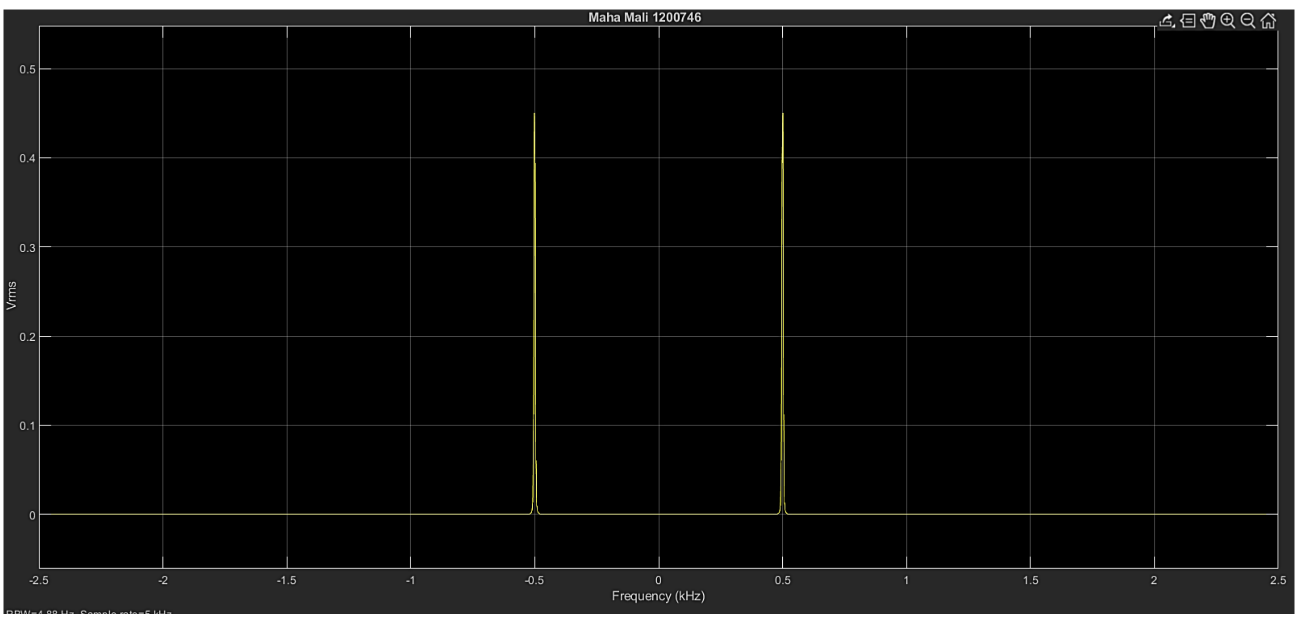


Figure 5: Frequency Domine

$$M(t) = 1coos(1000\pi t)$$

$$M(f) = \frac{1}{2}\delta(f - 500) + \frac{1}{2}\delta(f + 500)$$

The figure 5 show that we have two delta one at 500 Hz, and another on -500 Hz , according the equation for m(f).

Modulated signal s(t)

Time Domine

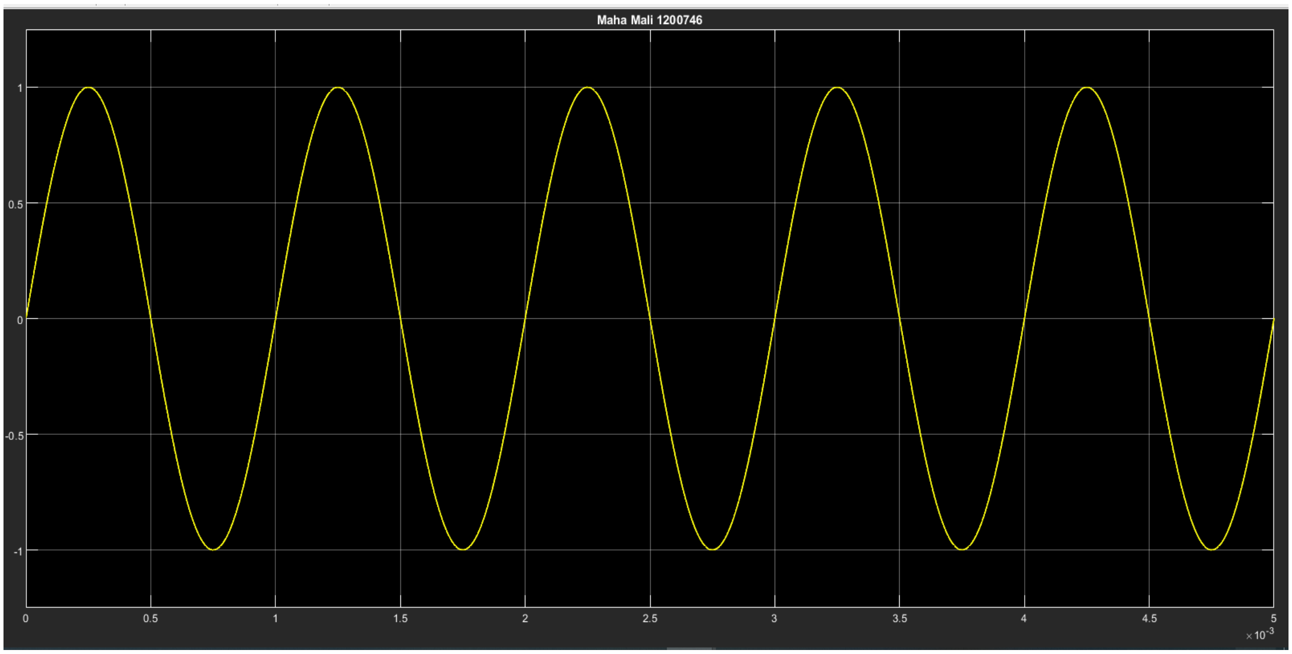


Figure 6: Modulated signal In Time Domine

Frequency Domine

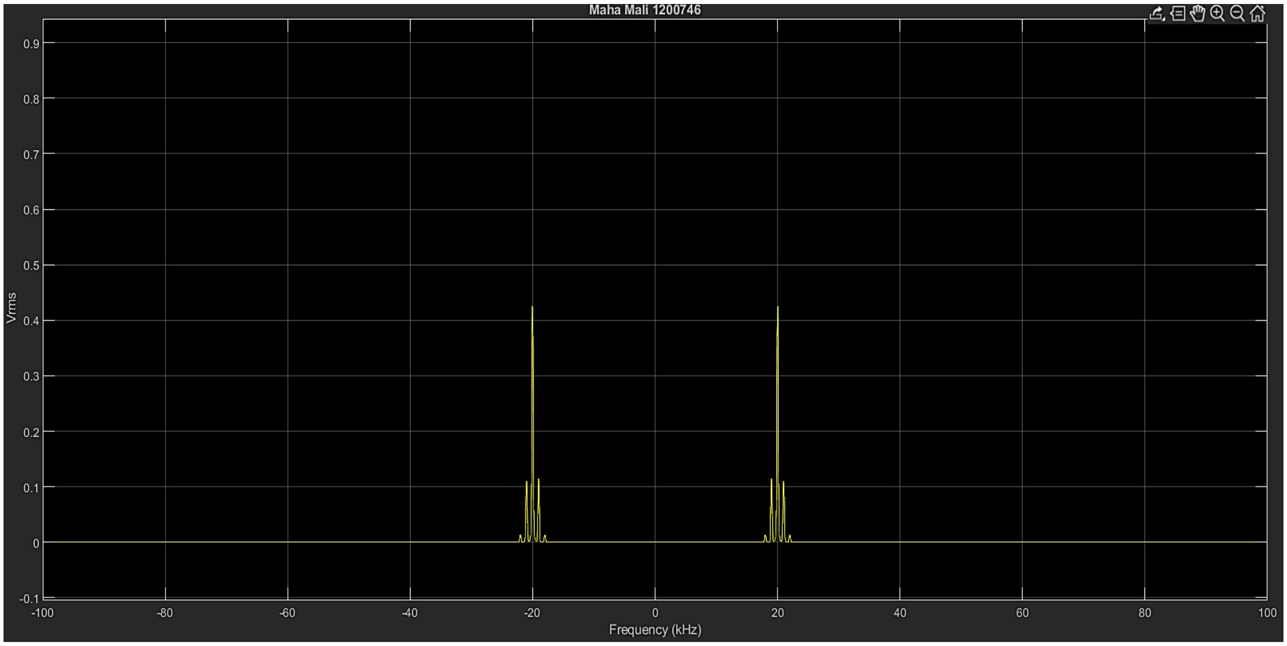
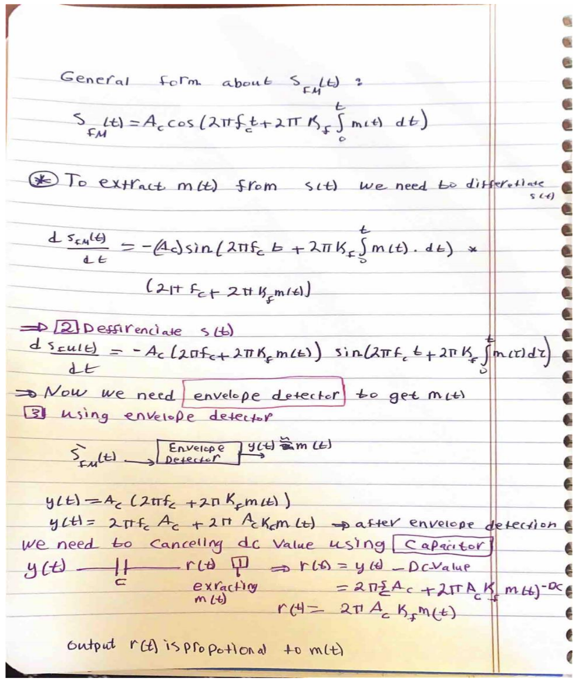


Figure 7: Modulated signal in frequency Domine

Differentiate s(t) with respect to t and plot ds(t)/dt

By Hand Solution



General form about $S_{FM}(t)$:

$$S_{FM}(t) = A_c \cos\left(2\pi f_c t + 2\pi K_f \int_0^t m(t)\, dt\right)$$

(*) To extract m(t) from s(t) we need to differetiate s(t)

$$\frac{d\, s_{FM}(t)}{dt} = -(A_c)\sin\left(2\pi f_c t + 2\pi K_f \int_0^t m(t)\,.\, dt\right) \times (2\pi f_c + 2\pi K_f m(t))$$

⇒ $\boxed{2}$ Desfirenciate s(t)

$$\frac{d\, s_{FM}(t)}{dt} = -A_c (2\pi f_c + 2\pi K_f m(t)) \sin\left(2\pi f_c t + 2\pi K_f \int_0^t m(\tau) d\tau\right)$$

⇒ Now we need $\boxed{\text{envelope detector}}$ to get m(t)

$\boxed{3}$ using envelope detector

$$\hat{S}_{FM}(t) \longrightarrow \boxed{\text{Envelope Detector}} \xrightarrow{y(t)} \approx m(t)$$

$y(t) = A_c (2\pi f_c + 2\pi K_f m(t))$

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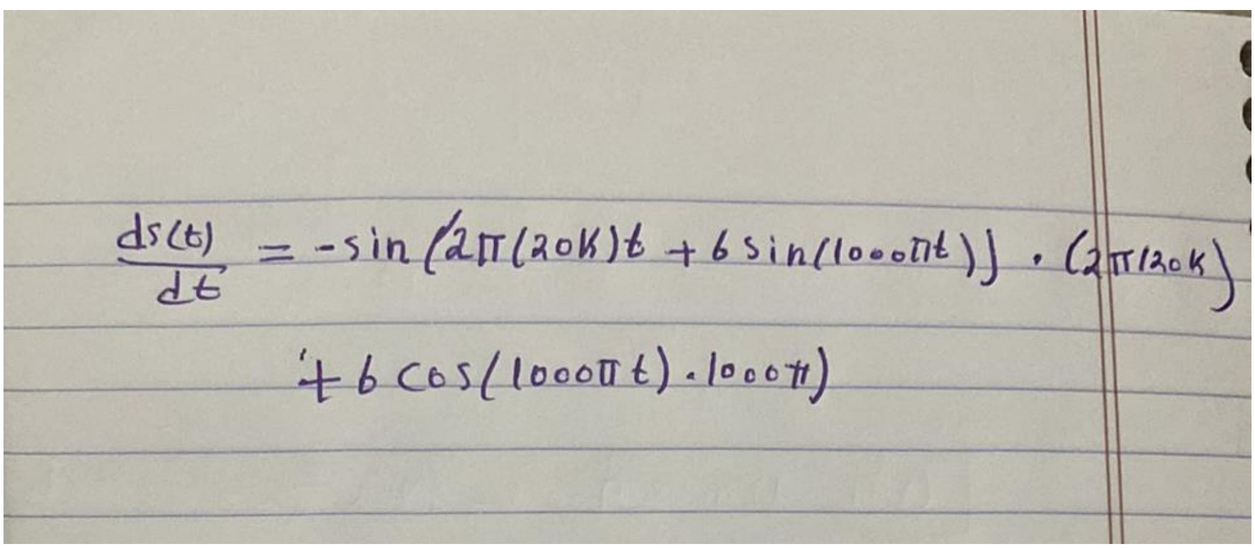
$= 2\pi f_c A_c + 2\pi A_c K_f m(t) - DC$

$r(t) = 2\pi A_c K_f m(t)$

output r(t) is propotional to m(t)



$$\frac{ds(t)}{dt} = -\sin\left(2\pi(20K)t + 6\sin(1000\pi t)\right) \cdot \left(2\pi(20K) + 6\cos(1000\pi t)\cdot 1000\pi\right)$$

Figure 8: Differentiate s(t)

The differentiation of function s(t) unveils a transition from a rapidly changing frequency modulation (FM) waveform to a slower amplitude modulation (AM) pattern. The original FM waveform, characterized by a 20,000 Hz carrier frequency and modulation, evolves into the derivative waveform ds(t)/dt. This shift from FM to AM-like behavior is a result of differentiation's emphasis on higher frequencies and its impact on reshaping signal traits

Using Simulink

Block Diagram

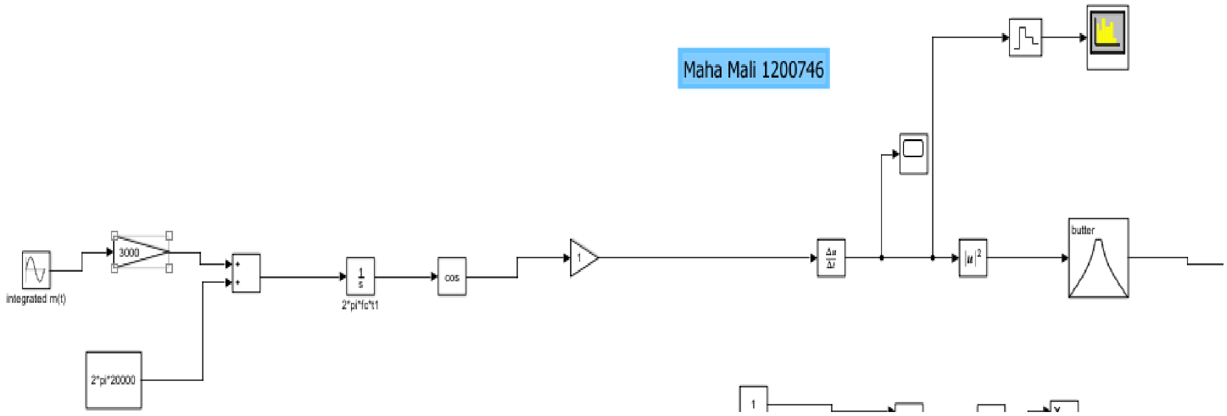


Figure 9: Block Diagram to Differentiate s(t)

Time domine

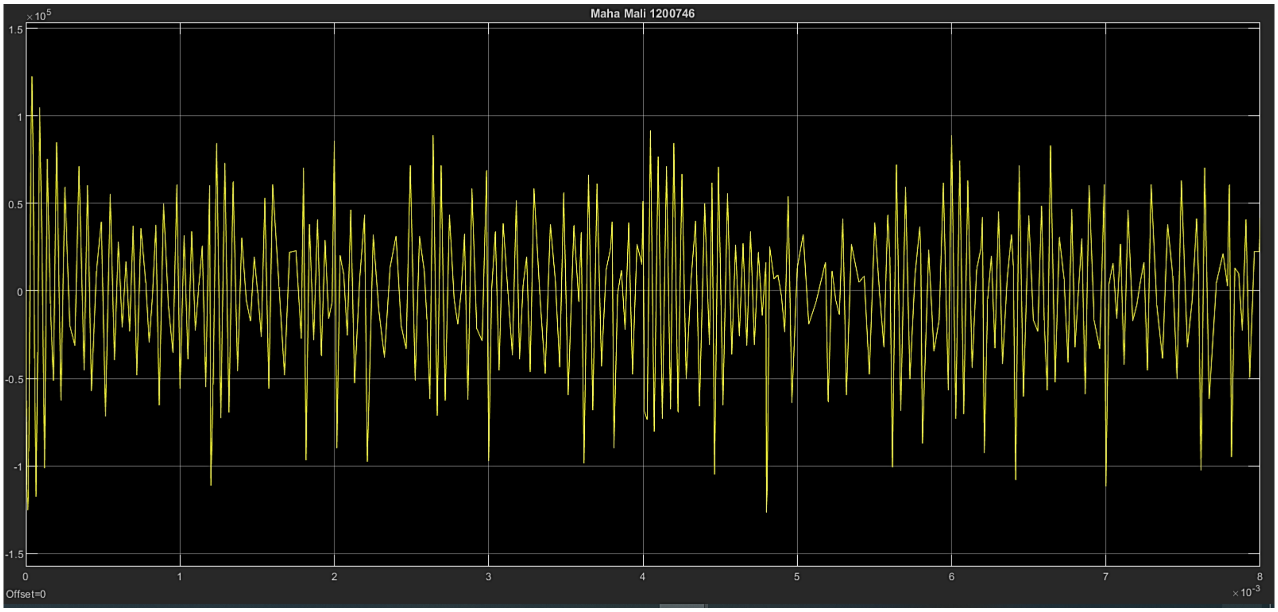


Figure 10: *Differentiate s(t) in time domine*

Frequency domine

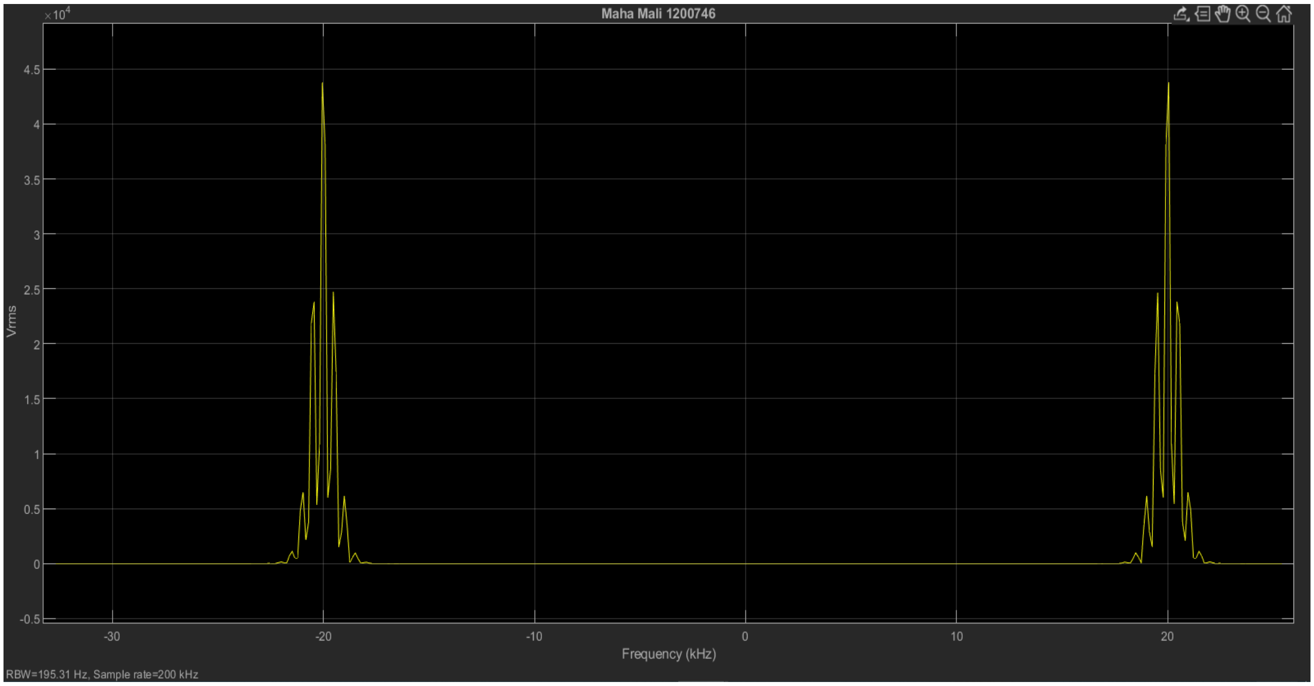
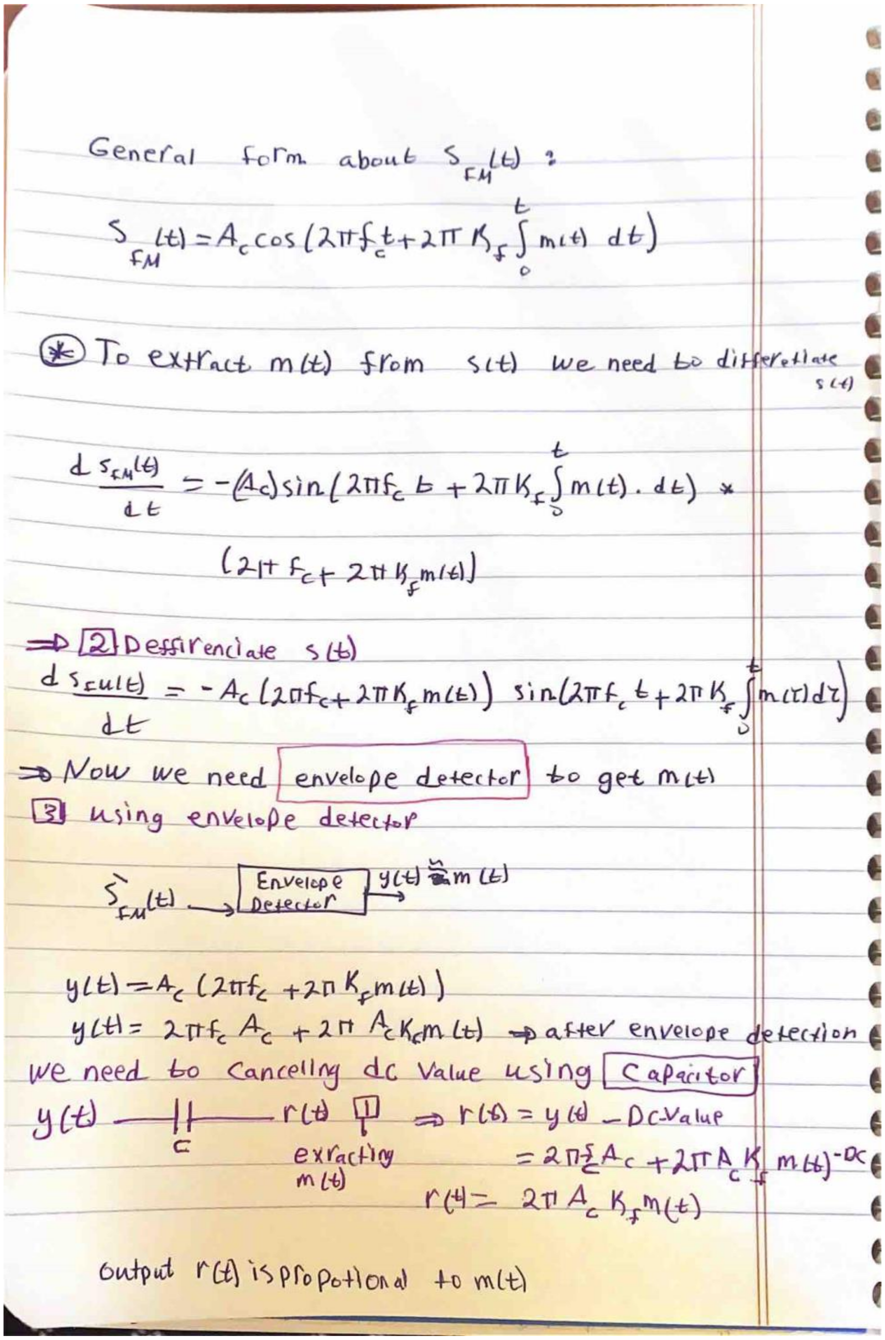


Figure 11: Differentiate s(t) in frequency domine

Apply ds(t)/dt to an ideal envelope detector

By Hand Solution



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y(t) —||— r(t) $\boxed{1}$ ⇒ $r(t) = y(t) - \text{DC Value}$

C

extracting m(t)

$= 2\pi f_c A_c + 2\pi A_c K_f m(t) - DC$

$r(t) = 2\pi A_c K_f m(t)$

output r(t) is propotional to m(t)

Figure 12: Apply ds(t)/dt to an ideal envelope detector

Extract message signal by using phase-locked loop (PLL)

Block Diagram

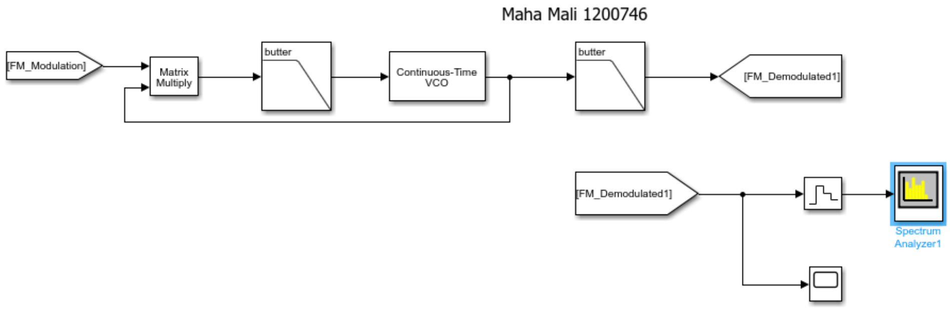

Figure 13:FM Demodulation by PLL Block Diagram

In time Domine

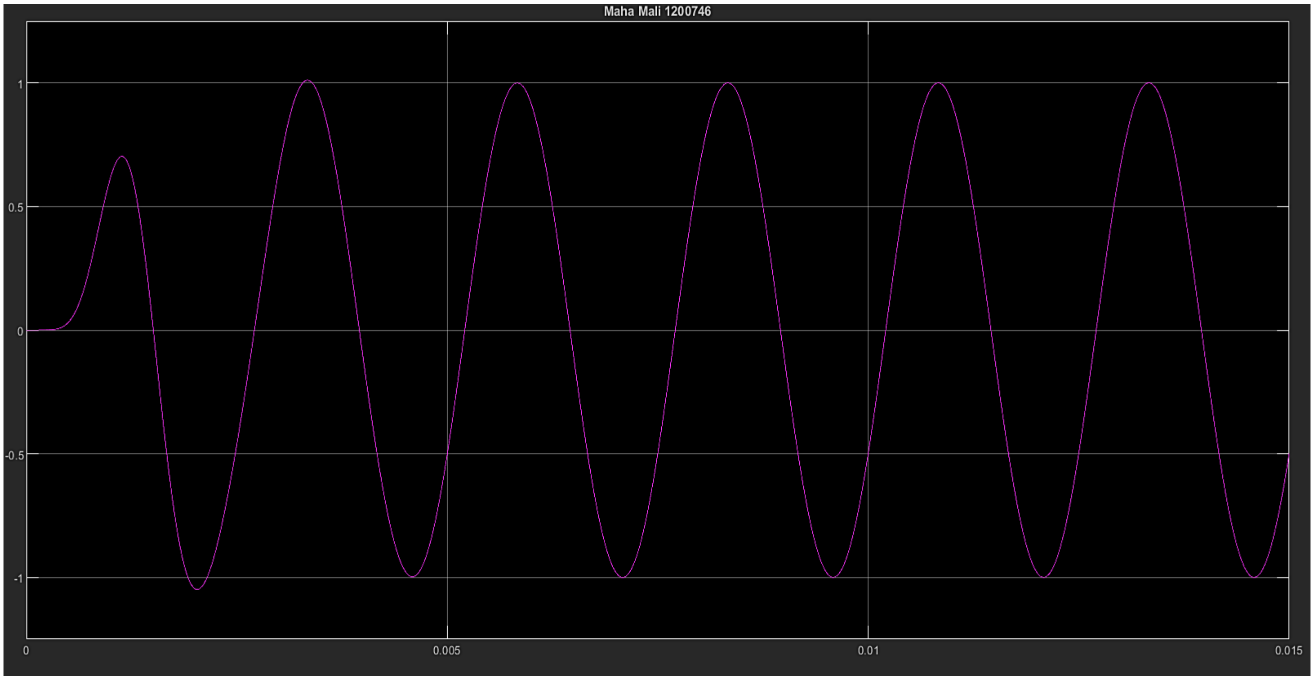

Figure 14: Demodulated signal in time domine

The figure 14 shows the amplitude of the demodulated signal has the same amplitude of message signal which is 1.

In frequency Domine

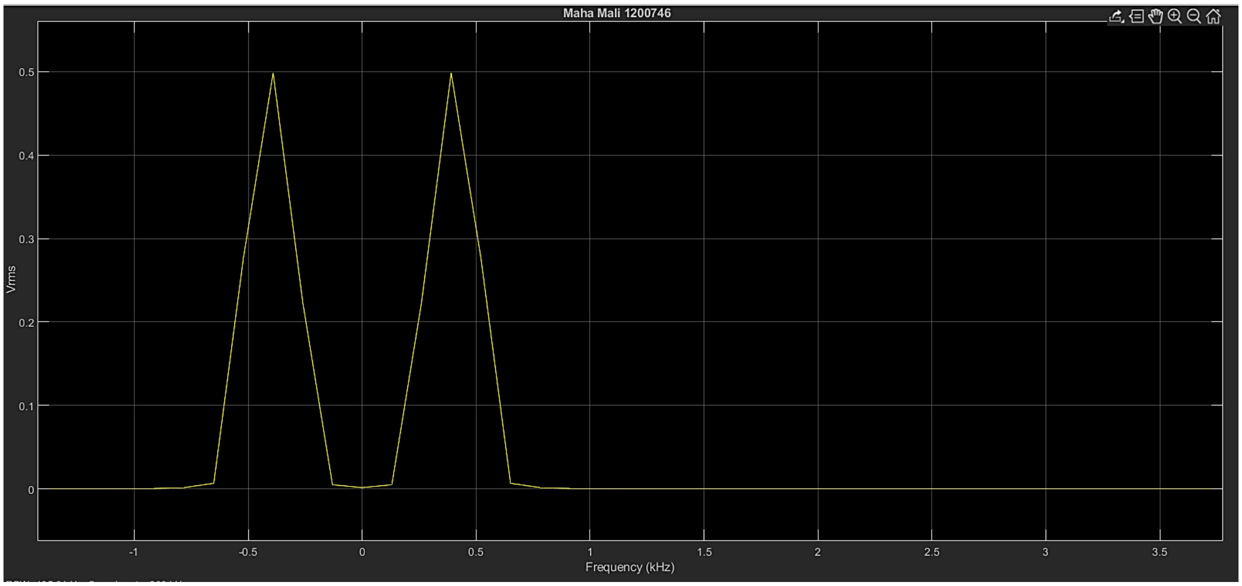

Figure 15: Demodulated signal in frequency domine

The figure show that the demodulated signal has the same frequency of message signal which is 500 Hz.

Extract the message signal by using the envelop detector

Block Diagram

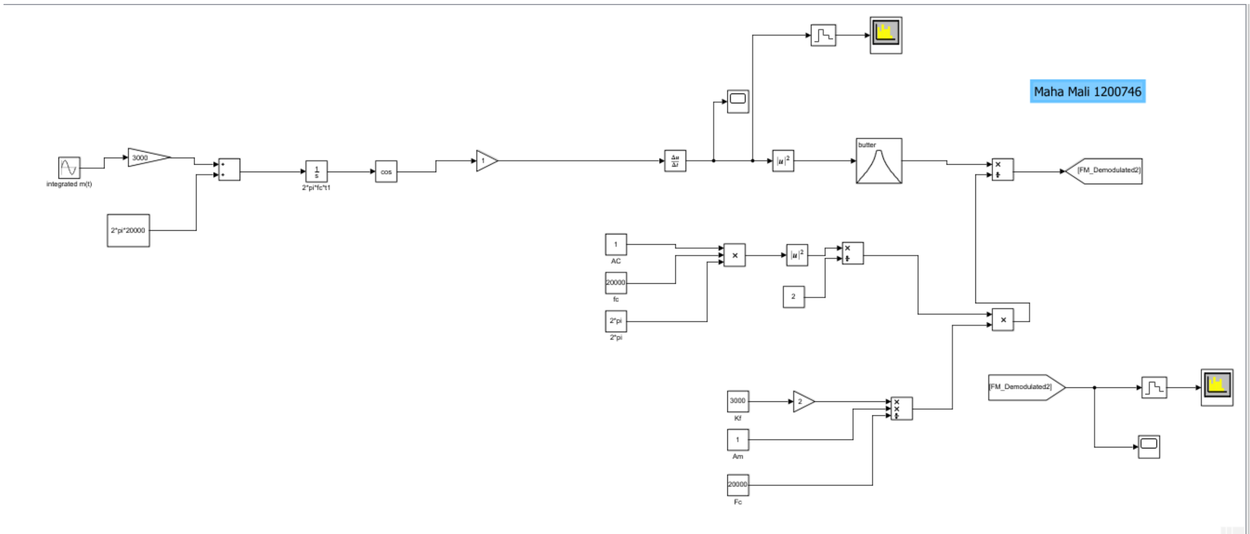

Figure 16::FM Demodulation by using the envelop detector Block Diagram

In Time Domine

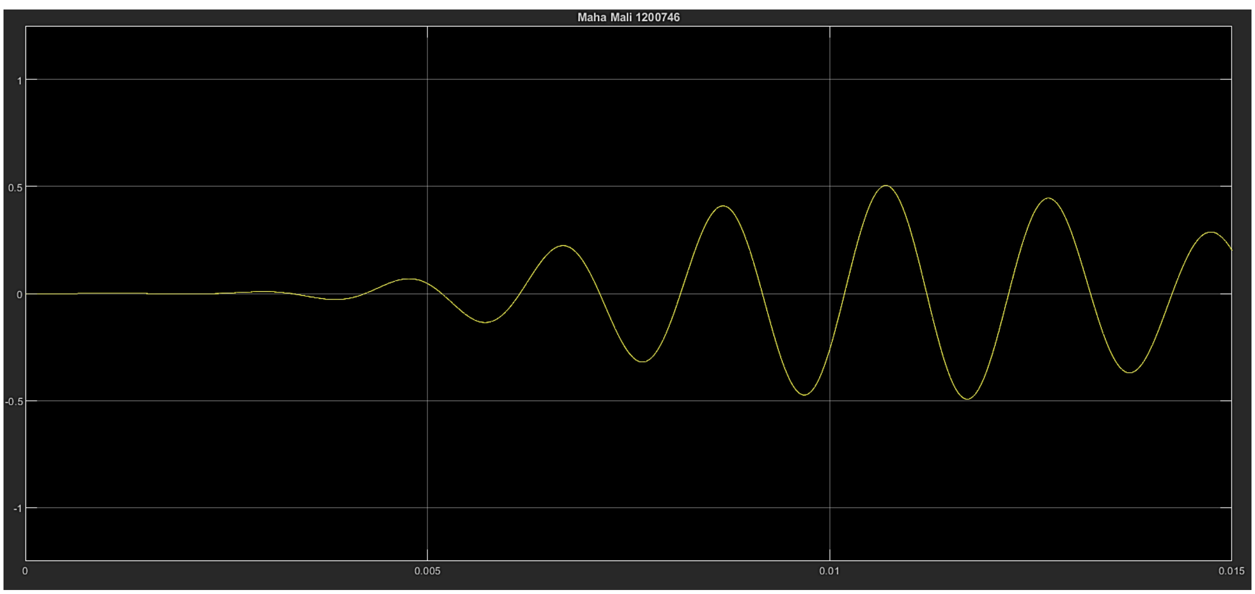

Figure 17: Demodulated signal in time domine

In frequency Domine

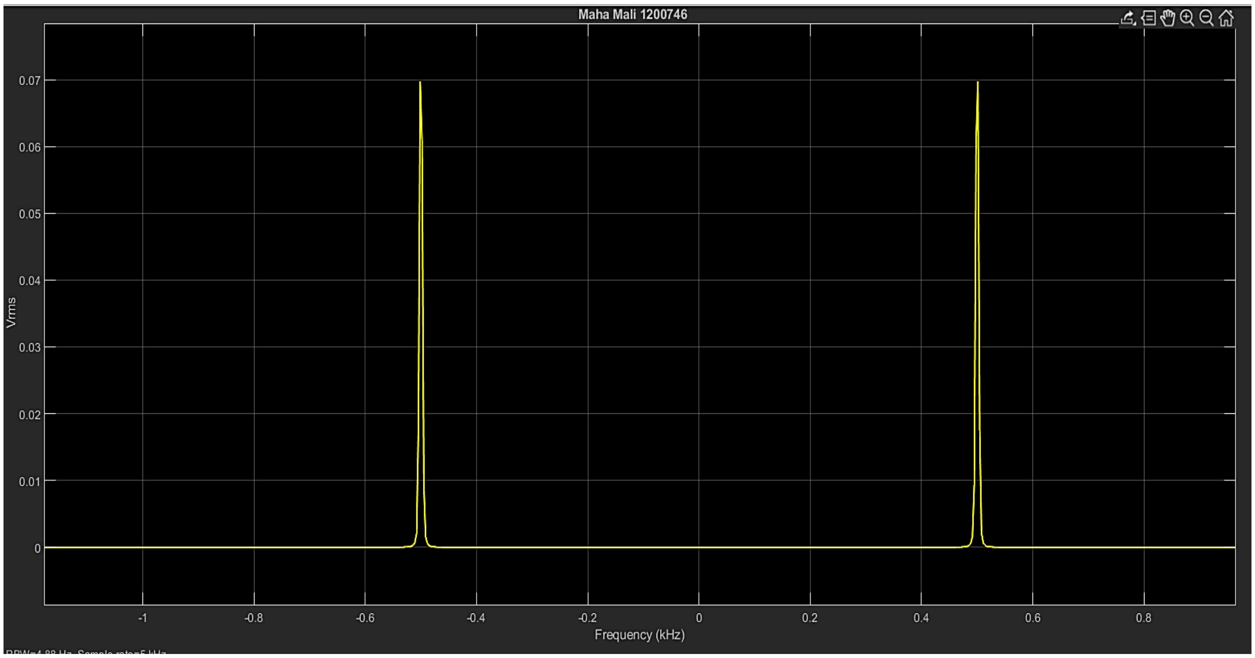

Figure 18: Demodulated signal in time domine

The figure show that the demodulated signal has the same frequency of message signal which is 500 Hz.