BIRZEIT UNIVERSITY

Faculty of Engineering & Technology

Electrical and Computer Engineering Department

Communication Laboratory - ENEE4113

Prelab Exp4 FM Modulation

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Section: 6

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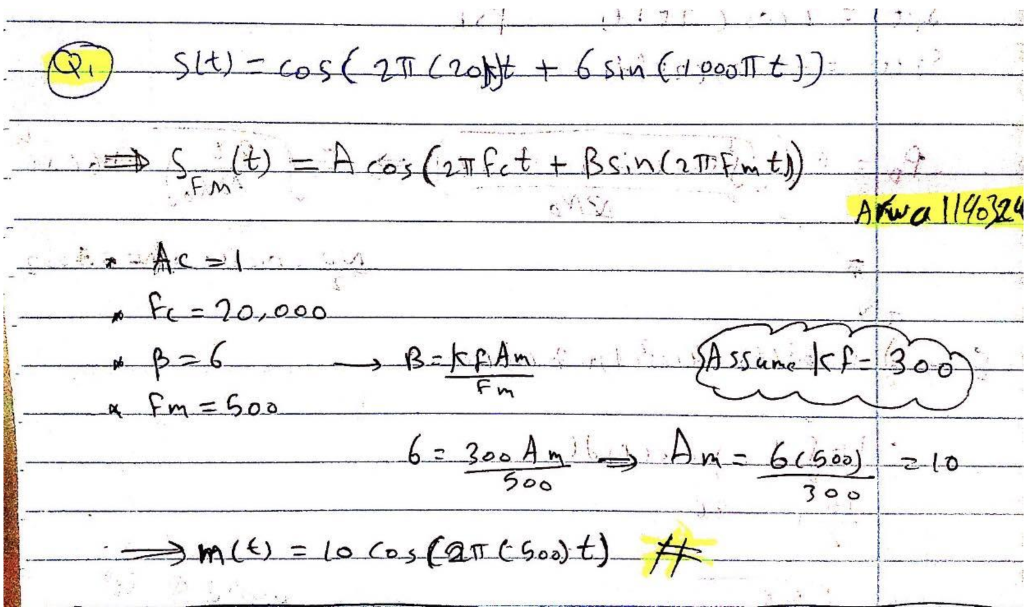
Software Prelab:

Consider the frequency modulated signal:

$$s(t) = \cos(2\pi(20k)t + 6\sin(1000\pi t))$$

Build a Simulink model in a MATLAB Simulink that [***Take plots in time and frequency domains***]:

1. Extract the message signal m(t) from s(t). ***[by hand solution]***.



Q1 $s(t) = \cos(2\pi(20k)t + 6\sin(1000\pi t))$

$\Rightarrow S_{FM}(t) = A\cos(2\pi f_c t + \beta \sin(2\pi f_m t))$

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- $A_c = 1$
- $f_c = 20{,}000$
- $\beta = 6 \rightarrow \beta = \frac{k_f A_m}{f_m}$ Assume $k_f = 300$
- $f_m = 500$

$6 = \frac{300 A_m}{500} \Rightarrow A_m = \frac{6(500)}{300} = 10$

$\Rightarrow m(t) = 10\cos(2\pi(500)t)$ #

Fig1: Extract m(t) from s(t) by hand solution.

2. Plot 5 cycle from message signal m(t) and s(t) versus t. ***[by Simulink]***.

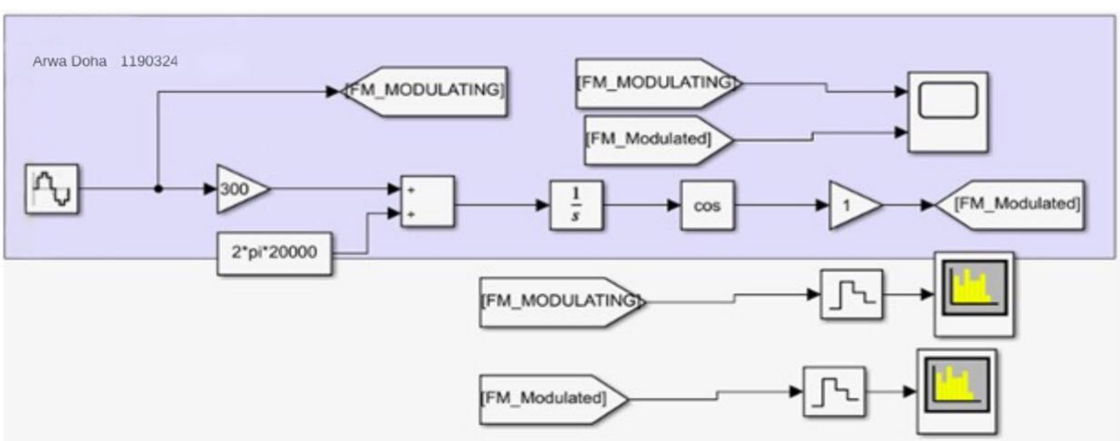

Fig2: Block diagram of 5 cycle from m(t) and s(t).

In the time-domain waveform results for message Signal m(t) and Modulated Signal S(t):

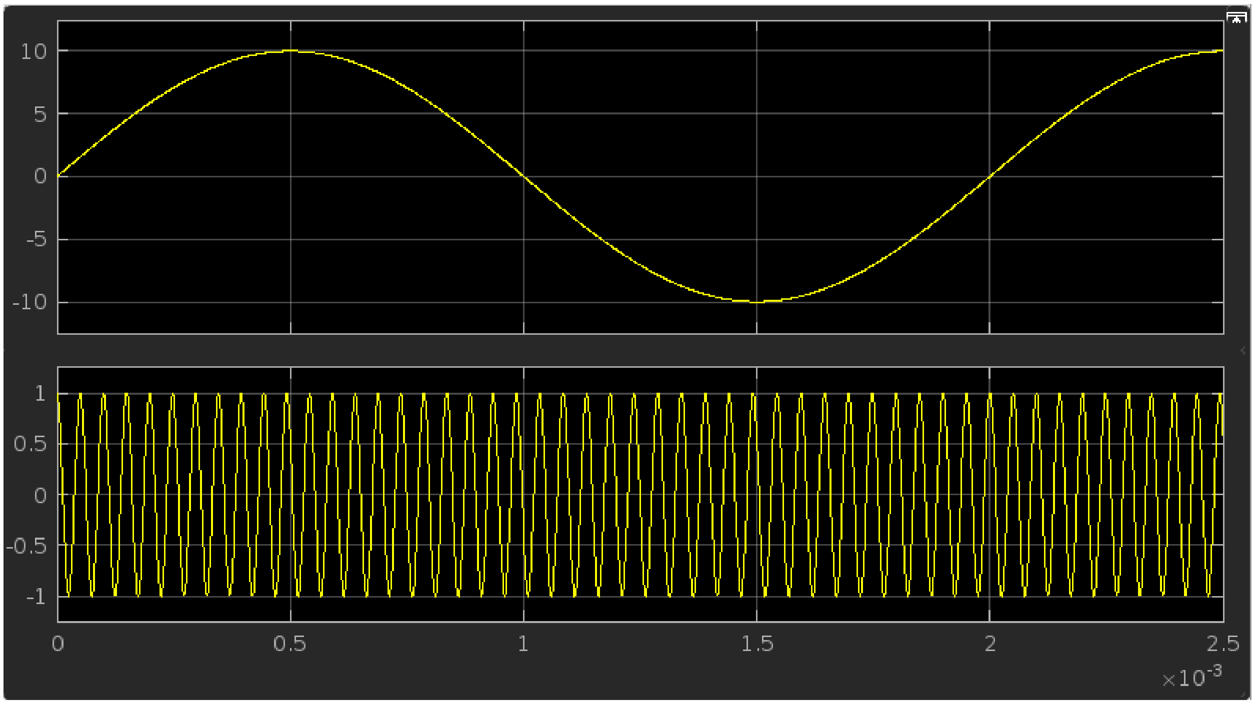

Fig3: m(t) & s(t) in time domin

In the freq-domain waveform results for message Signal m(t) and Modulated Signal S(t)

For 5 cycles, but the high frequency of the modulated signal makes it challenging to discern in this representation.:

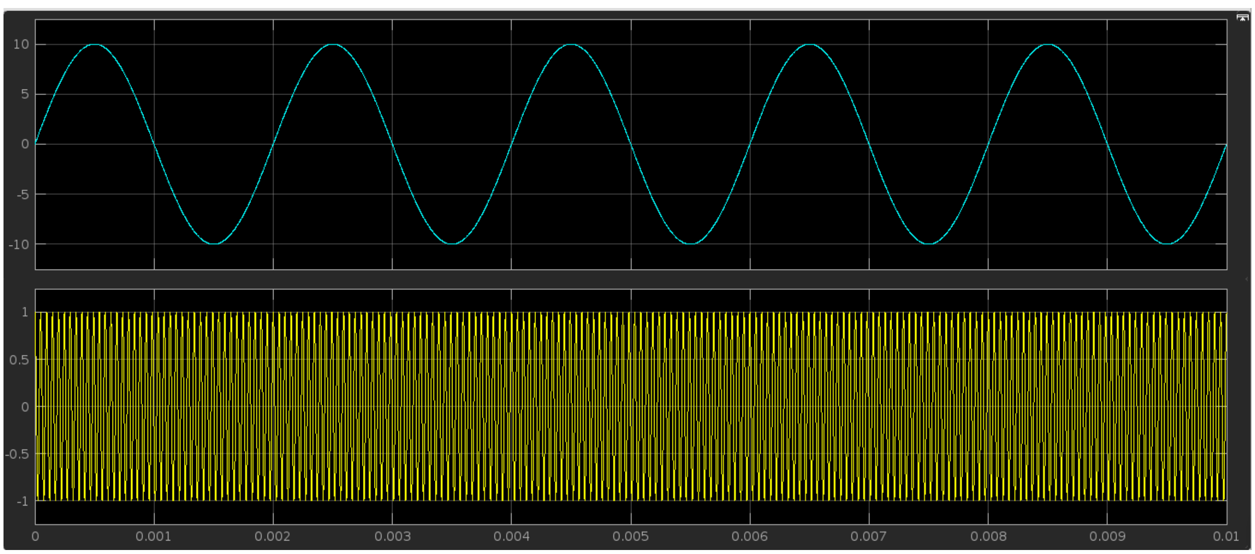

Fig4: m(t) & s(t) for 5 cycles in time domin

In the freq-domain waveform results for message Signal: $M(F) = 5\delta(f-500) + 5\delta(f+500)$

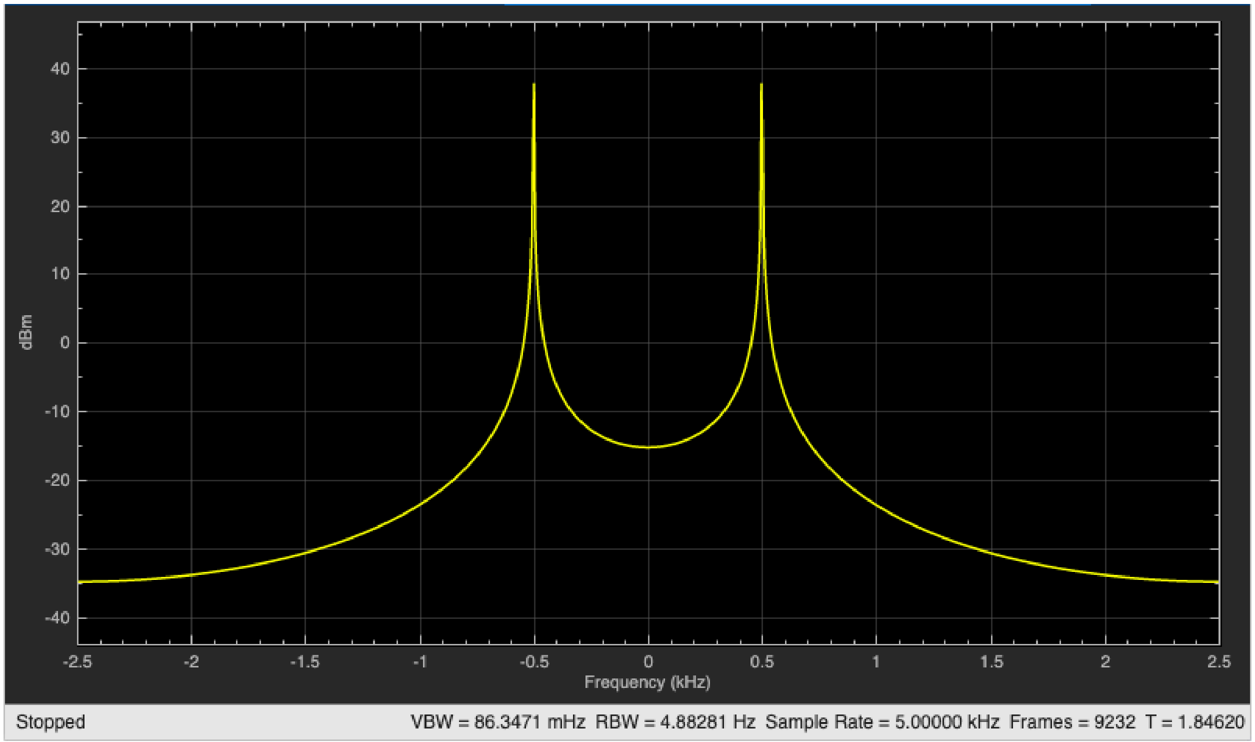

Fig5: Message Signal m(t) in Frequency Domain

In the freq-domain waveform for Modulated Signal S(F):

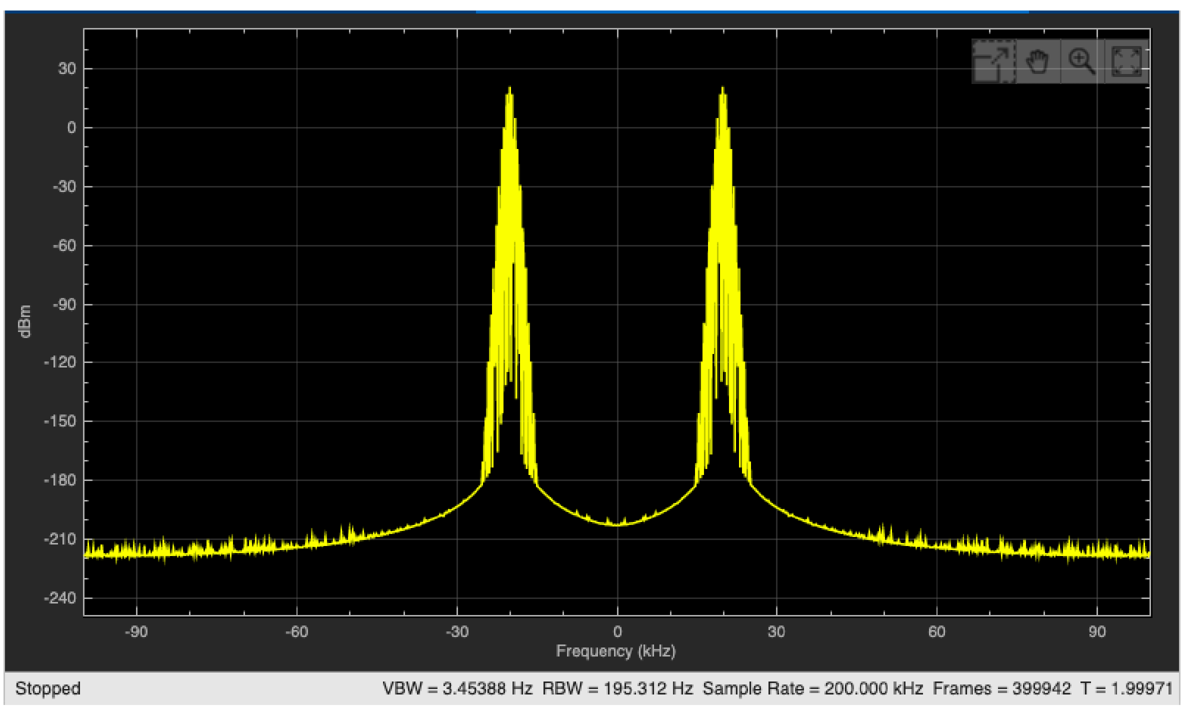

Fig6: Modulated Signal S(t) in Frequency Domain

3. Differentiate s(t) with respect to t and plot ds(t)/dt. Notice how this operation transforms an FM waveform into an AM waveform. ***Write your observation and conclusions.*** ***[by hand then use Simulink to observe your result].***

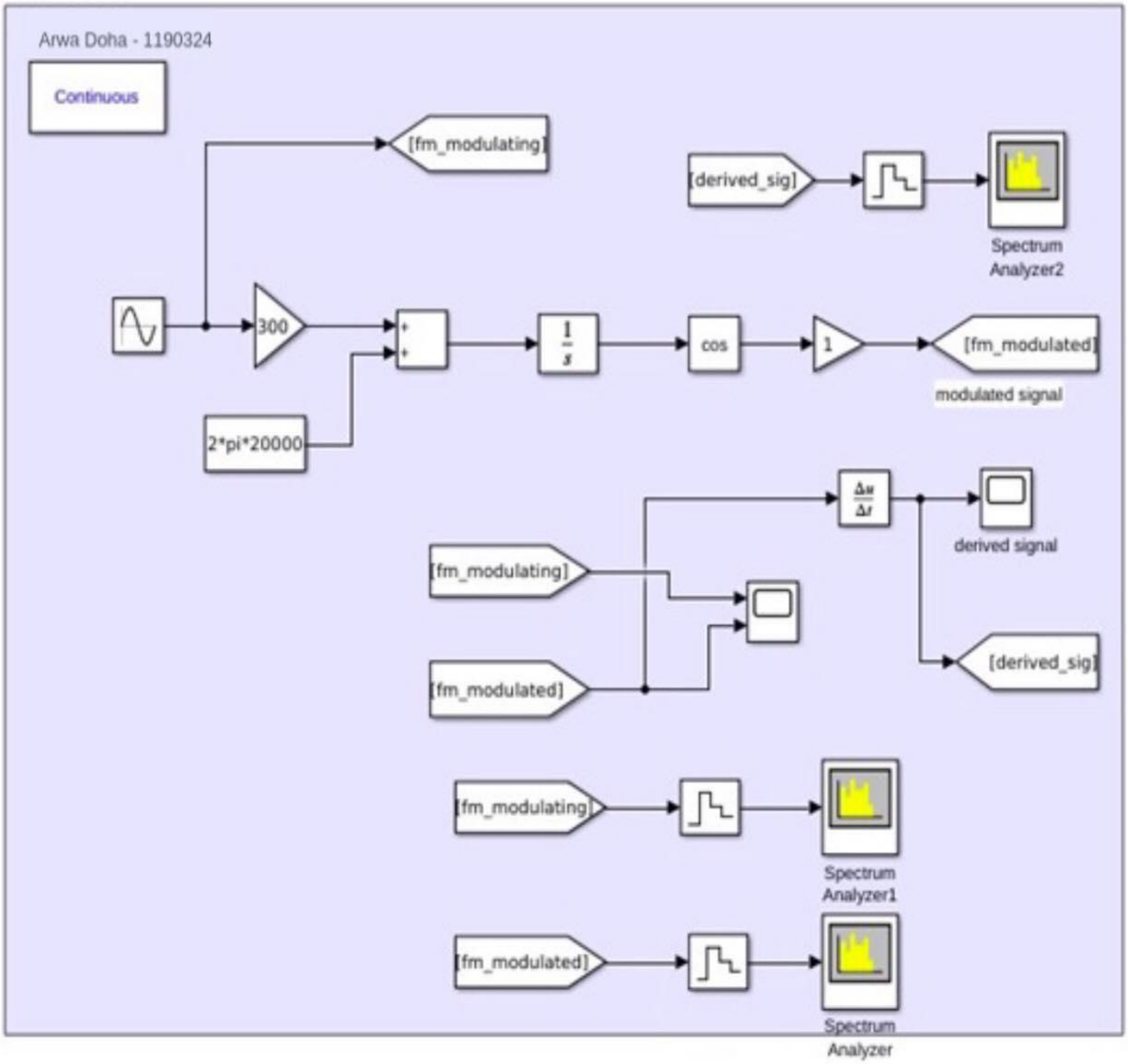

Fig8: Simulink block diagram of "FM to AM Transformation"

In the time-domain waveform for derived S(t) modulated signal:

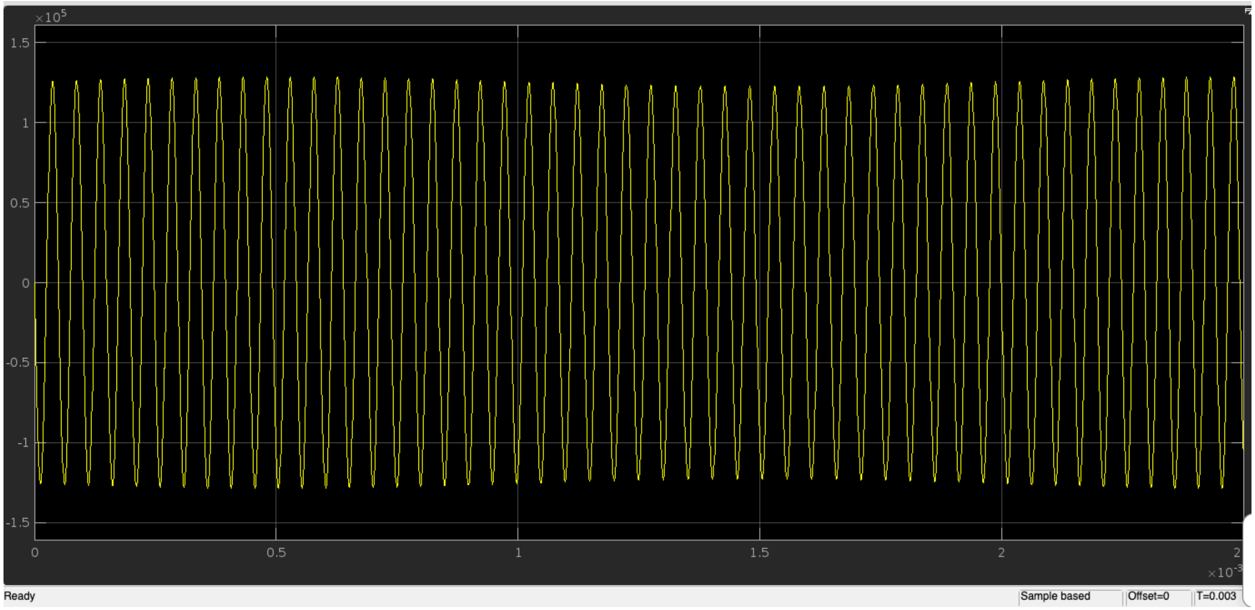

Fig9: Simulink block diagram in time domain of derived S(t)

In the frequency-domain waveform for derived S(t) modulated signal:

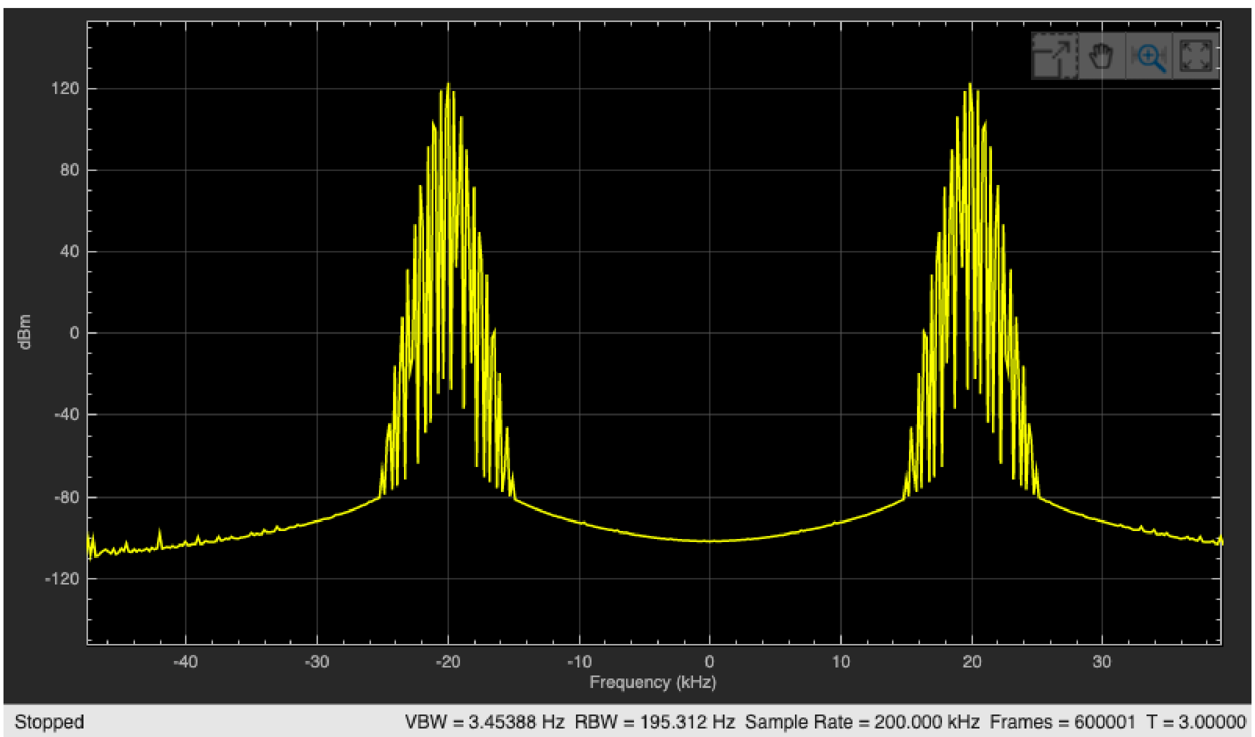

Fig10: Simulink block diagram in freq domain of derived S(t).

Analytical Solution by Hand: Differentiation of S(t)

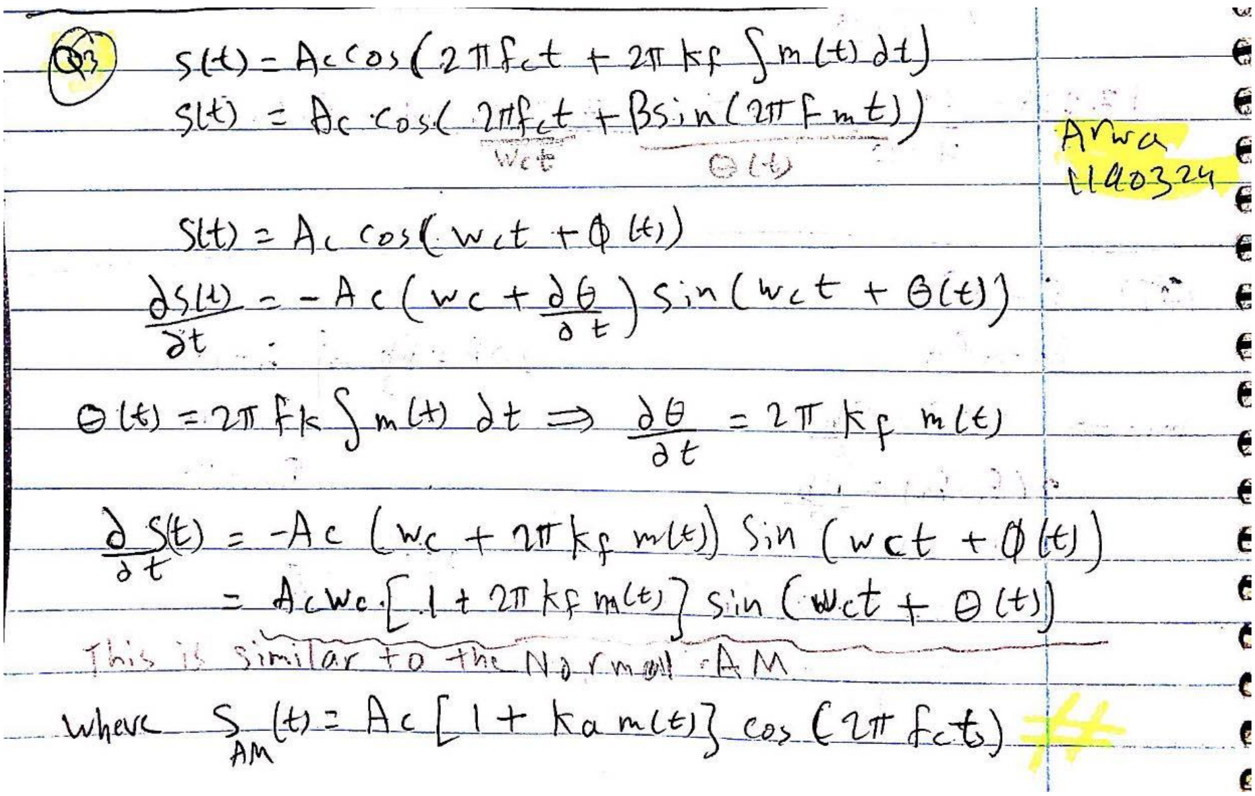

Fig7: Differentiate s(t) by hand solution

Observation & Result:

As observed in the waveform, when we differentiate S(t) (FM), we obtain a wave that looks like an AM waveform. As observed in the figures previously, deriving S(t) returns a negative sine wave, but if we overlook the negative sign in the calculations, we have a result =

$$Acwc[1 + \frac{2\pi kfm(t)}{wc} \sin(wct + \theta)]$$

Inside In this scenario, we multiply the carrier angular frequency (wc) by the carrier amplitude (Ac), and within the parentheses, there is an addition of 1 to a sensitivity constant multiplied by the message signal (m(t)).

The coefficient in this signal closely resembles that of Amplitude Modulation (AM), expressed as Ac [1 + Ka*m(t)] *cos(wct). When the Frequency Modulation (FM) modulation is differentiated with respect to time, it transforms into Amplitude Modulation.

4. Apply ds(t)/dt to an ideal envelope detector, subtract the dc term and show that the detector's output is linearly proportional to m(t). ***Write your observation and conclusions.*** ***[by hand solution].***

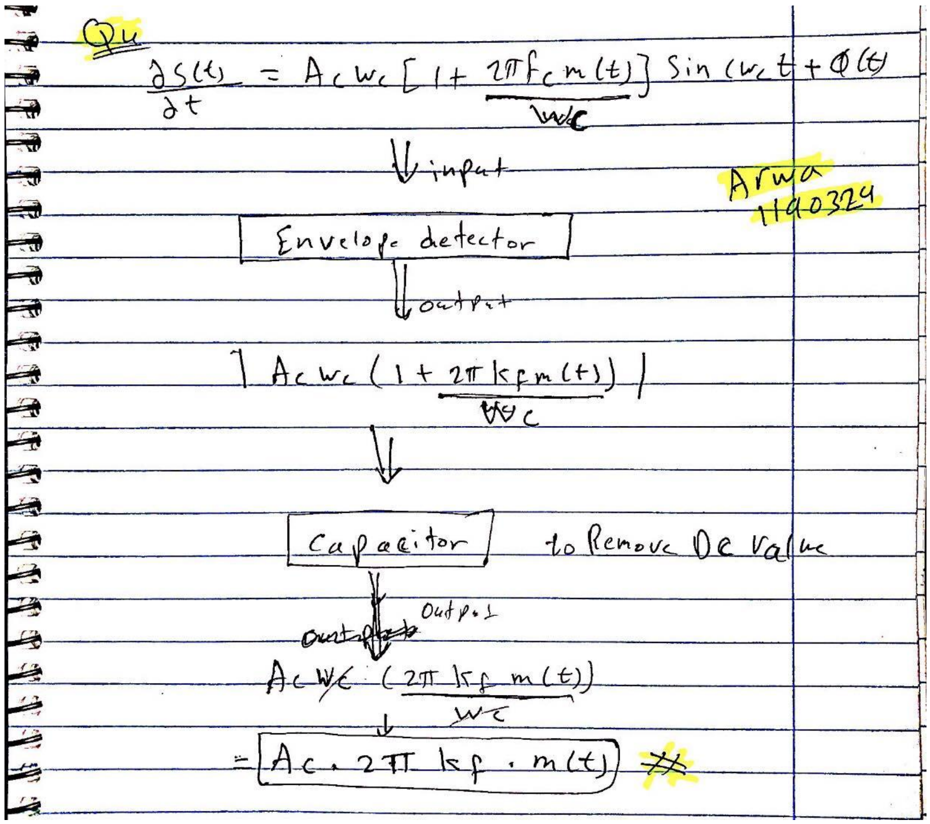

Fig11: Apply ds(t)/dt to an ideal envelope detector

Observation & Result:

Applying the derivative of S(t) to an envelope detector yields an output representing the amplitude of the sine function, given by:

$$AcW_c[1 + \frac{2\pi k f m(t)}{W_c}].$$

When graphed, this results in a cosine wave elevated by the DC value Ac*Wc. Subsequently passing this signal through a capacitor eliminates the DC component, resulting in an output of [Ac * 2π * kf * m(t)]

Notably, this output is directly proportional to the message signal, with the amplitude of the message signal multiplied by [Ac * 2π * kf]. Consequently, through this demodulation technique utilizing an envelope detector, the original message signal can be successfully recovered.

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

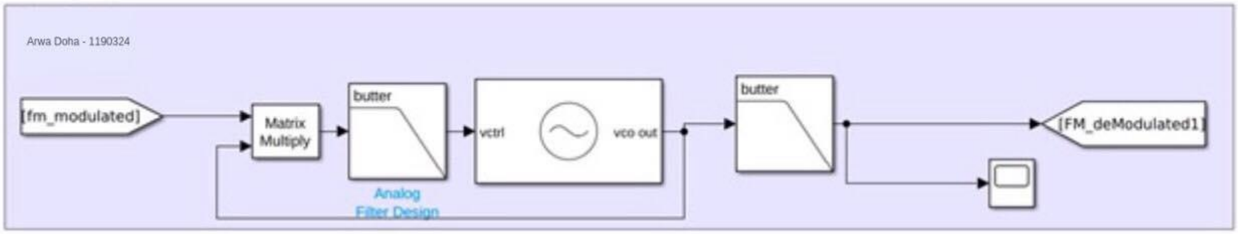

Fig12: Simulink block diagram of m(t) by using (PLL)

6. Extract the message signal by using the envelop detector.

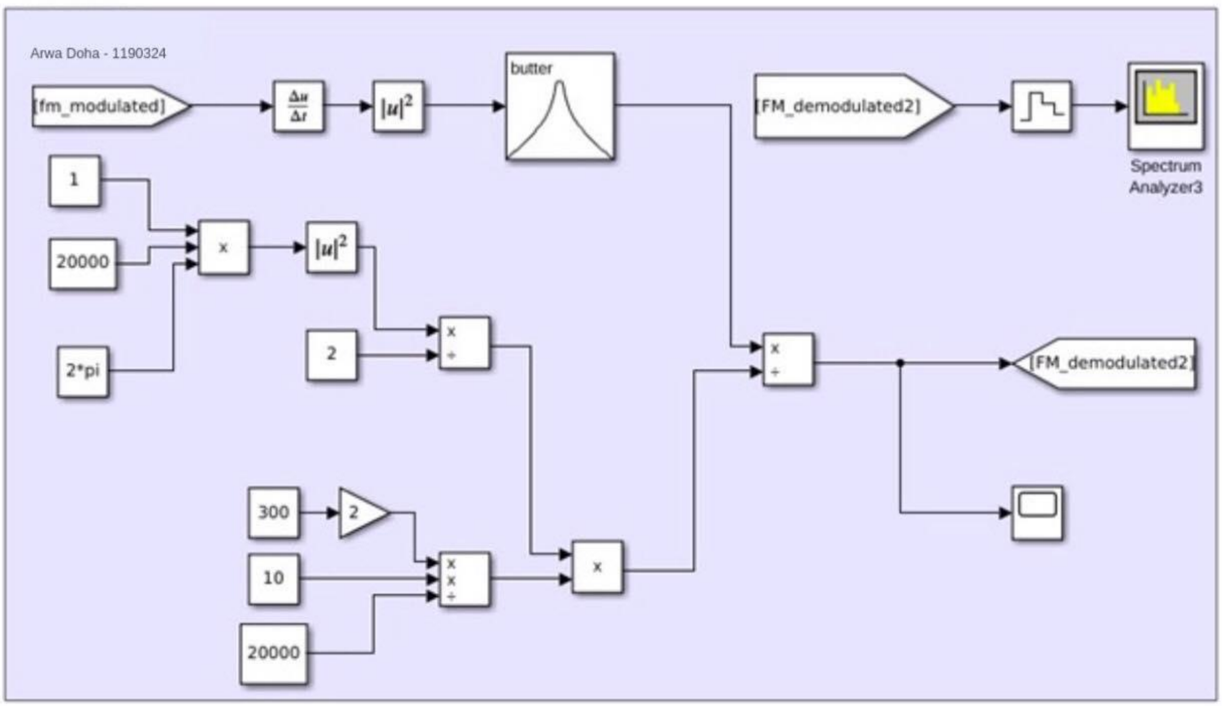

Fig13: Simulink block diagram of m(t) by envelop detector

Demodulated Signal in Time Domain (zoomed in when signal is stable)

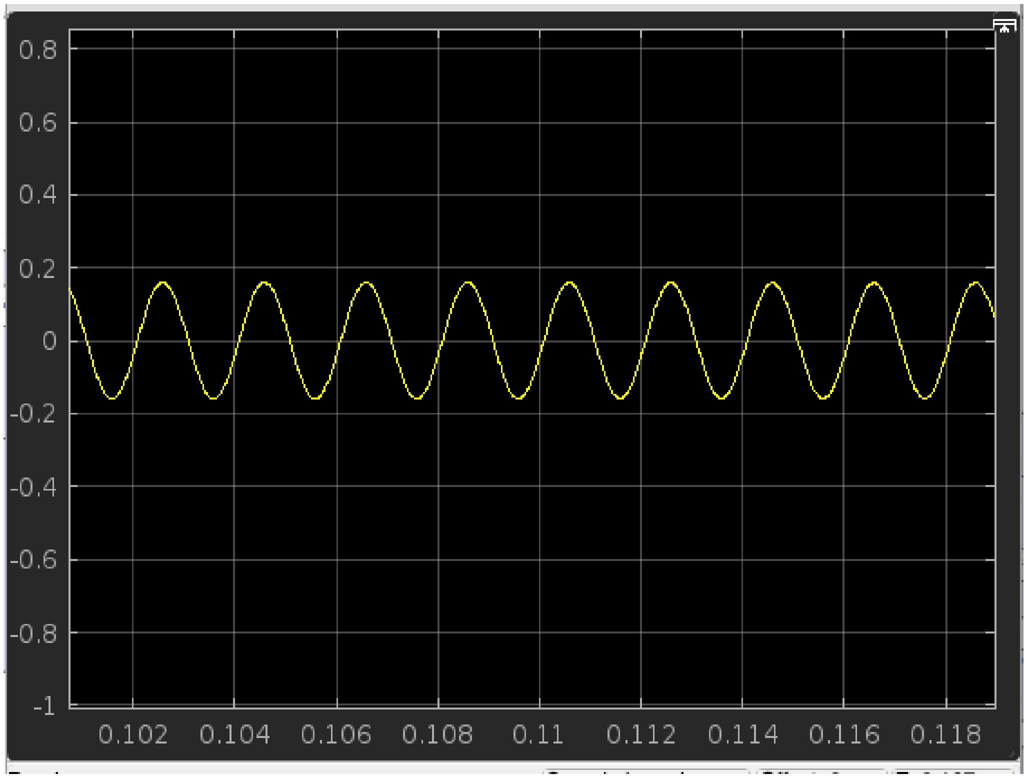

Fig13: Demodulated Signal in Time Domain

Demodulated Signal in Frequency Domain (fm=500hz)

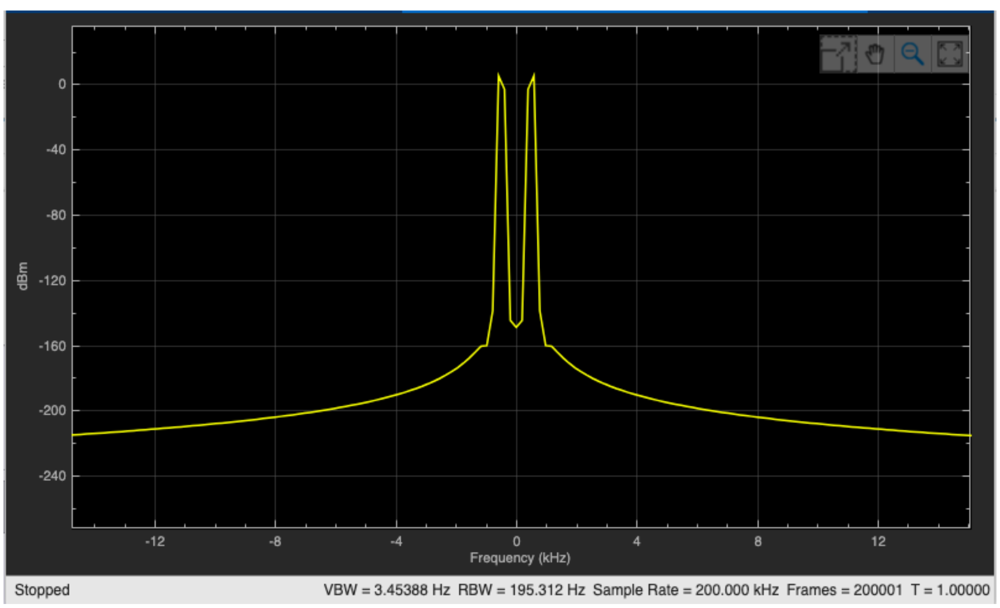

Fig14: Demodulated Signal in Frequency Domain.