Lab #2

Amplitude Modulation

Lab Group #20

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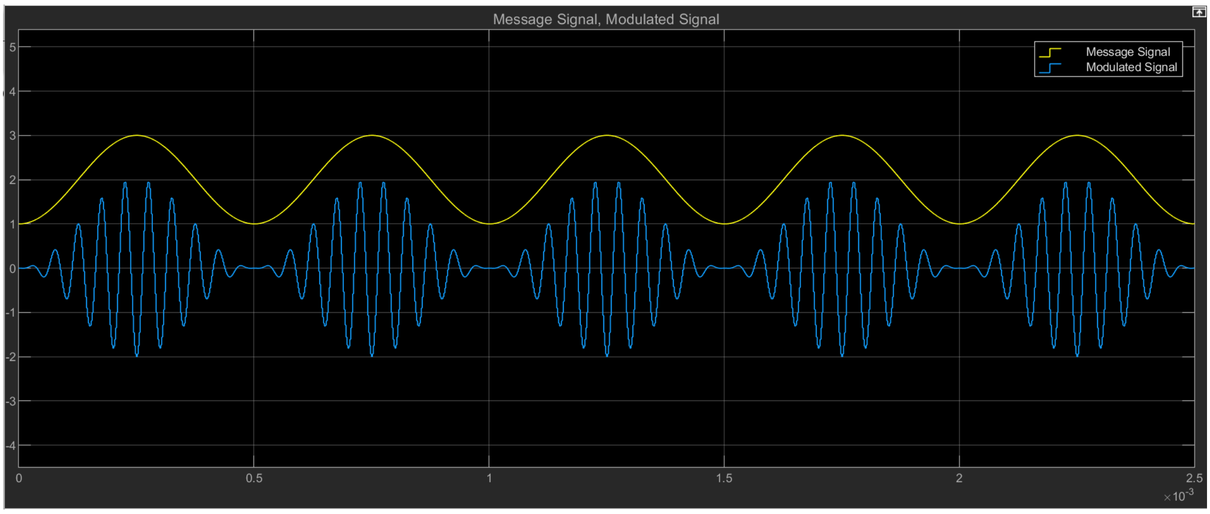
Section 1 - Modulation

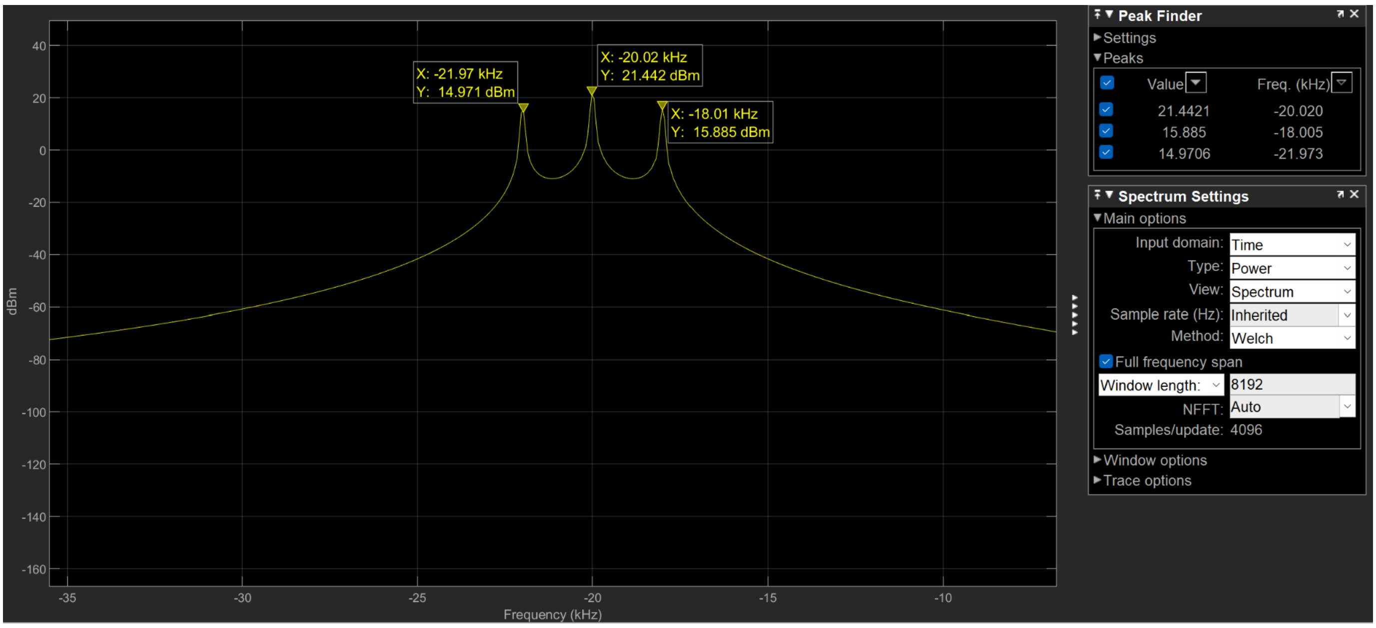
In this section a single tone message signal **cos(2 pi fm t)** is modulated with a carrier signal to create an AM signal. The resulted signal is as followers:

$s(t) = A_c[1 + \mu\cos(2\pi f_m t)]\cos(2\pi f_c t)$ **Where**

Message: Amplitude=1(V), Frequency=2 kHz
Carrier: Amplitude = Choose a value between 1 and 3 (V), Frequency=20 kHz
Modulation Index(μ): 1



**Plot 1.1 Scope Screenshot (Yellow- message signal + 2V DC Offset)
(Blue- Modulated Signal)**



Plot 1.2 Spectrum Analyzer Screenshot

Calculation of power efficiency:

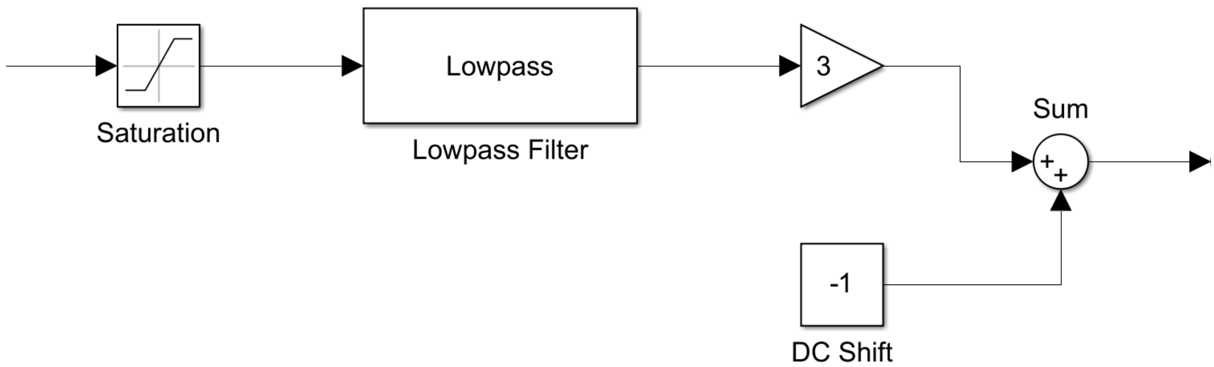
$$P_{(W)} = 1W \cdot 10^{(P_{(dBm)} / 10)} / 1000 = 10^{((P_{(dBm)} - 30) / 10)}$$

Power Table	dBm	Milli watts
Peak of Carrier Wave	21.422	138.73
Peak of Negative Side	14.971	31.41
Peak of Positive Side	14.885	30.80
Sum of Sidebands' Power	29.86	62.21
Total Power	51.278	200.94

Power efficiency = Sum of sidebands' power/Total Power = 62.21/200.94 = 31 %
The 2 % is due to rounding errors.

Section 2 - Demodulation with Envelope Detection

In this section we will demodulate the AM signal to compare it with the original message signal. The demodulation block is as the figure below consists of a saturation block, low pass filter, gain and a DC shift.



The following parameters were chosen for the blocks:

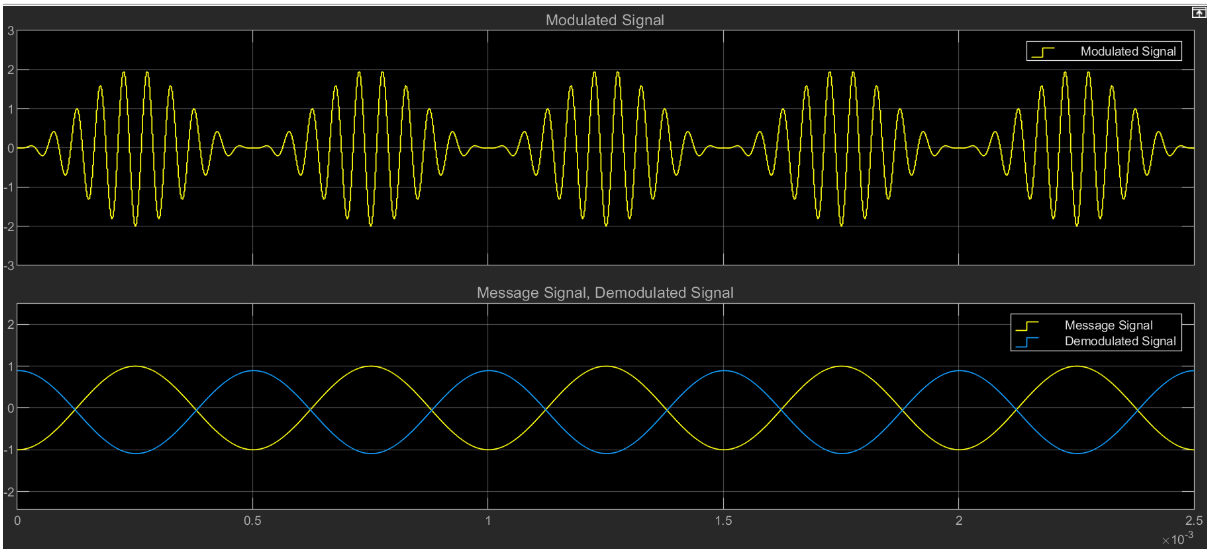
Lowpass Filter:

- Filter Type: FIR
- Passband Edge Frequency: Slightly larger than the frequency of the message (~4 KHz)
- Stopband edge frequency: ~10 KHZ
- Maximum passband ripple: between 0.1~1
- Maximum stopband attenuation: more than 80

Saturation:

Lower limit=0, Upper limit =2

The demodulated signal is plotted below:



Plot 2.1 Scope Screenshot

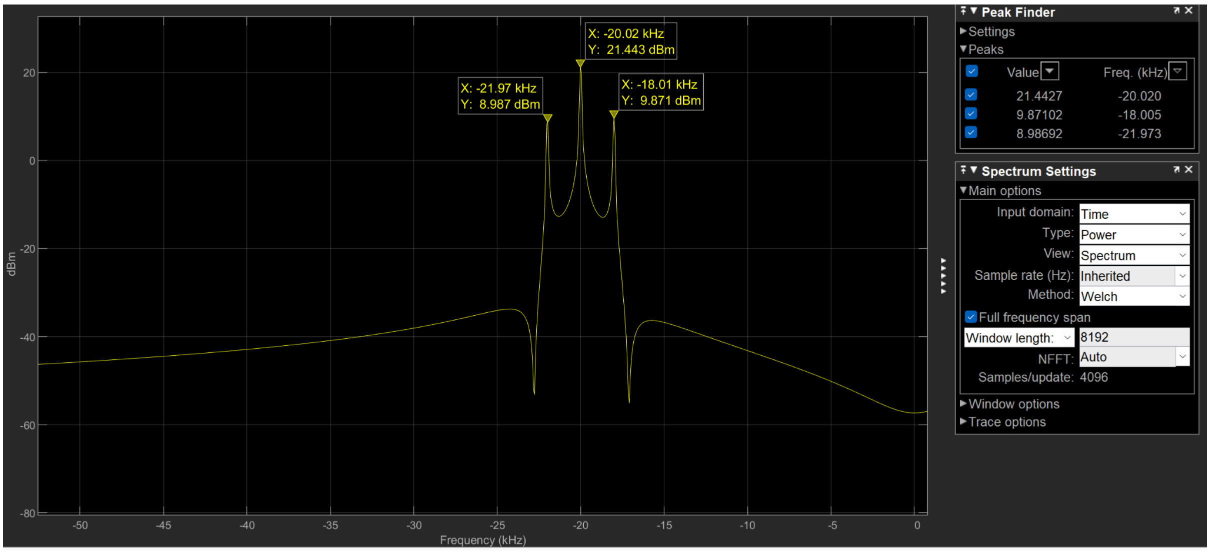
Note:

Demodulated signal is identical to the original message signal but comes with a 90° phase shift

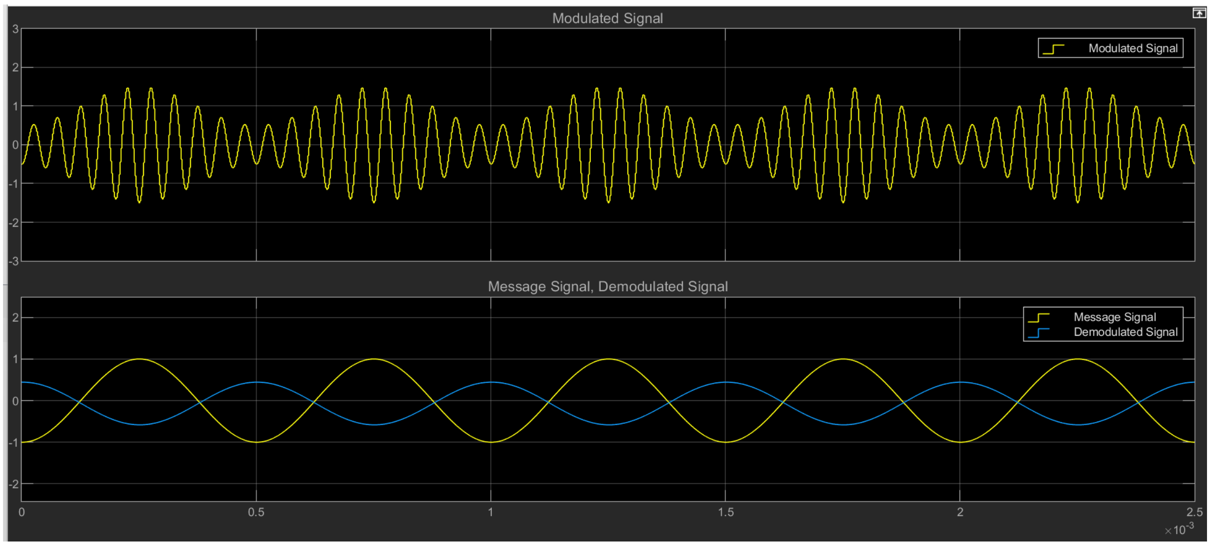
Section 3 - Effect of Modulation Index

Modulation Indexes chosen : 0.5, 0.75, 1.5

Modulation Index 0.5 Data:

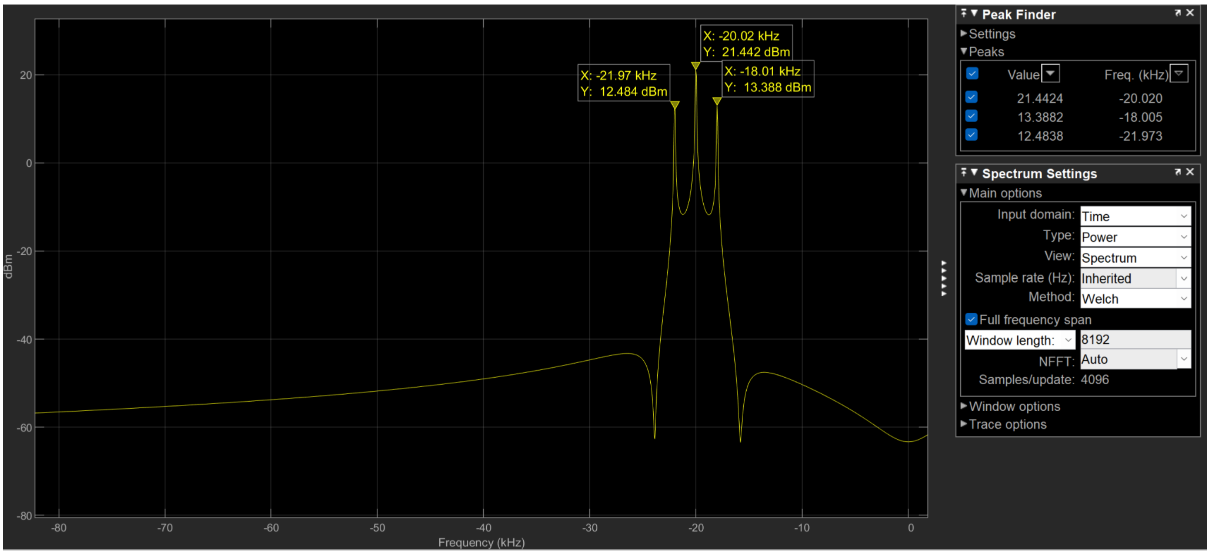


Plot 3.1 Modulation Index 0.5 Spectrum Analyzer Screenshot

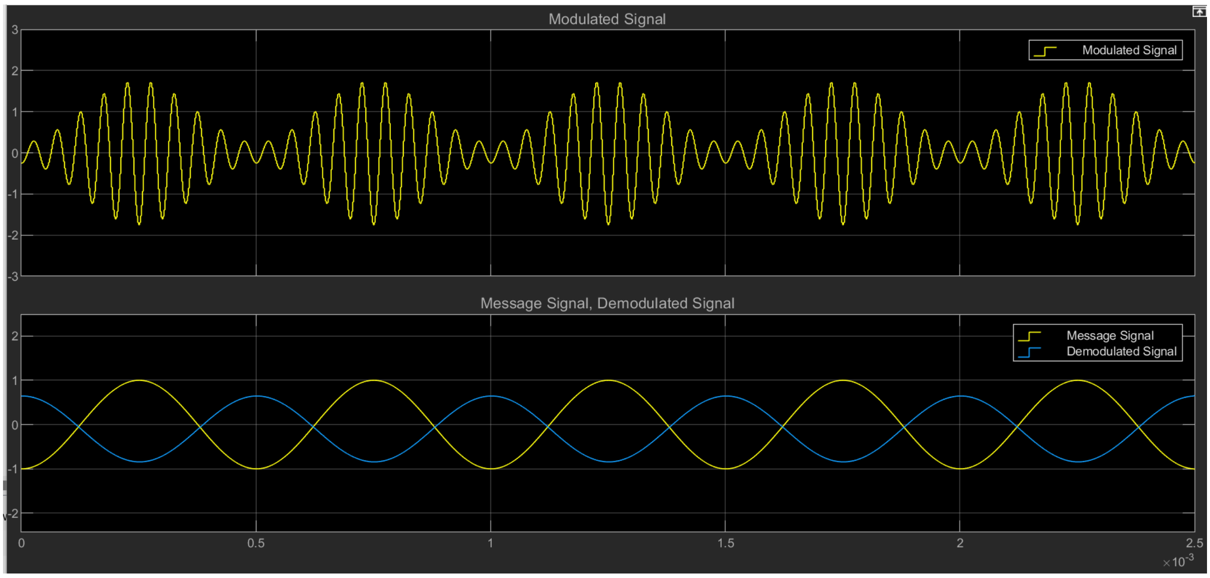


Plot 3.2 Modulation Index 0.5 Scope Screenshot

Modulation Index 0.75 Data:

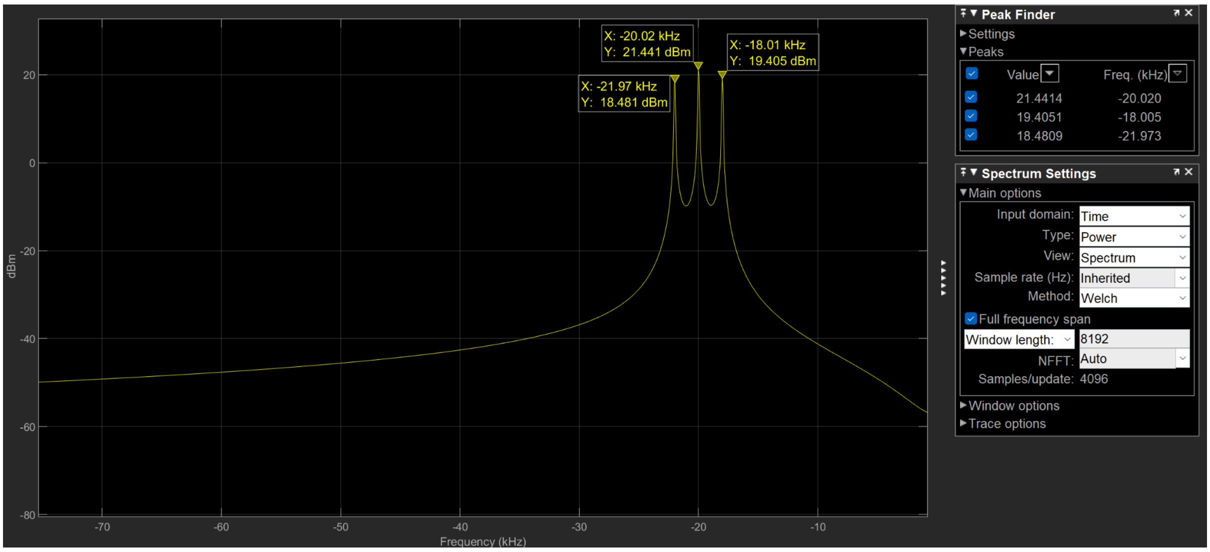


Plot 3.3 Modulation Index 0.75 Spectrum Analyzer Screenshot

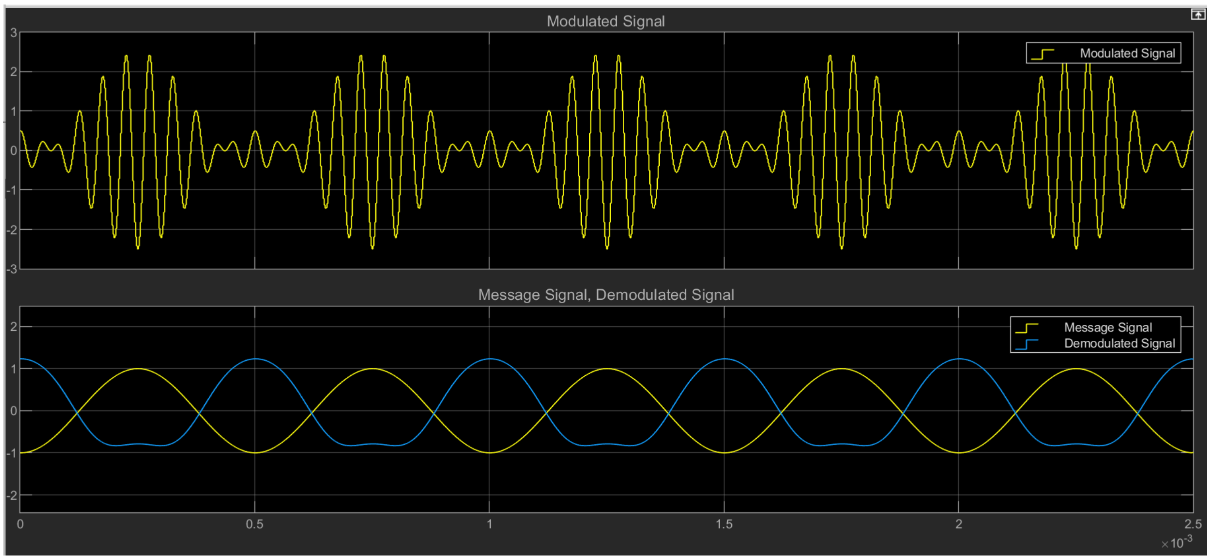


Plot 3.4 Modulation Index 0.75 Scope Screenshot

Modulation Index 1.5 Data:



Plot 3.5 Modulation Index 1.5 Spectrum Analyzer Screenshot



Plot 3.6 Modulation Index 1.5 Scope Screenshot

Power Efficiency Calculations:

Modulation Index	**0.5**	**0.75**	**1.5**
Carrier Frequency Power **(dBm)**	21.443	21.442	21.441
Upper Sideband Power **(dBm)**	8.987	12.484	18.481
Lower Sideband Power **(dBm)**	9.871	13.388	19.405
Carrier Frequency Power **(mW)**	139.411	139.380	139.348
Upper Sideband Power **(mW)**	7.919	17.717	70.486
Lower Sideband Power **(mW)**	9.707	21.817	87.197
Total Sideband Power **(mW)**	17.626	39.534	157.683
Total Signal Power **(mW)**	157.037	178.914	297.031
Calculated Efficiency	**11.22%**	**22.097%**	**53.086%**
Theoretical Efficiency	**11.1111%**	**21.95%**	**52.94%**

Table 3.1 Power Efficiency Calculations

Theoretical Formula: $\frac{\mu^2}{2+\mu^2} * 100\%$

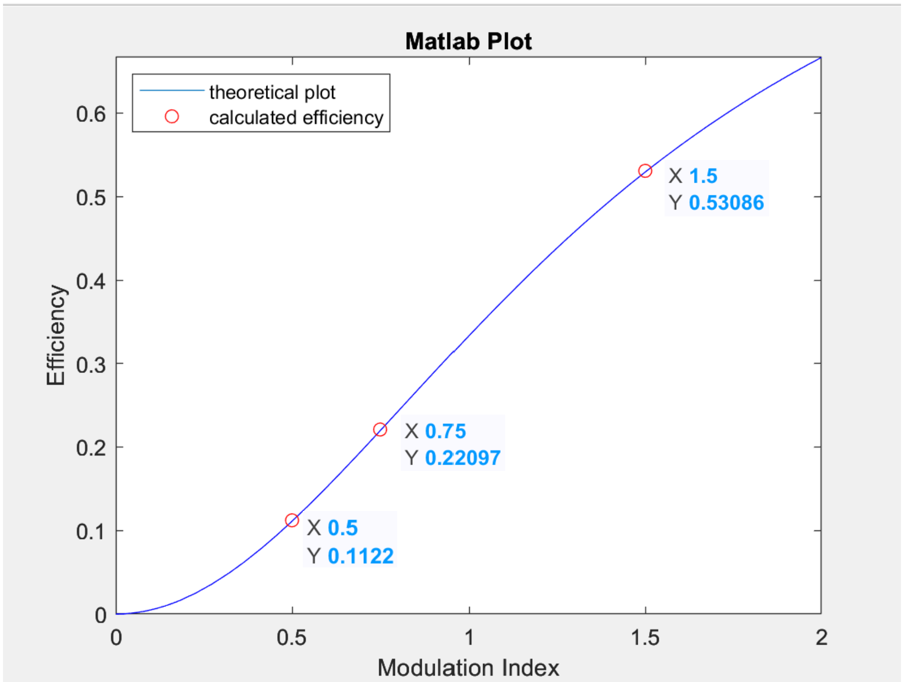
Calculated Efficiency: [1-(Carrier Frequency Power/Total Signal Power)]*100%

Section 4- Explanation

Explain the changes observed in the AM waveform in time and frequency domain as the modulation index is changed.

Explanation:

- In the time domain, as the modulation index increases, both Emax and the difference between Emax and Emin increase. Meaning, the amplitude increases. However, if the modulation index exceeds 1, the difference between Emax and Emin begins to decrease.
- In the frequency domain, a higher modulation index results in a higher power level (measured in dBm). This aligns with theoretical calculations of power efficiency. Higher modulation index results in a higher power efficiency.



Explanation:

- The simulation and theoretical results are very similar, indicating agreement between the two. As the modulation index increases, power efficiency also increases. However, it should be noted that theoretically, 100% efficiency can be achieved if the modulation index approaches infinity. In such a scenario, the carrier signal in the AM signal becomes insignificant, and the transmission essentially becomes an attempt to send the amplified message signal alone.

For the case of modulation index above 100%, explain the output of the demodulator. Is the original message recovered from the modulated signal? Why?

Explanation:

- Overmodulation occurs when the modulation index exceeds 1, as shown by the demodulated signal with a modulation index of 1.5 in section 4.3. In such cases, it is impossible to perfectly recover the modulated signal because the negative portion of the message cosine signal becomes distorted due to overlapping of the upper and lower envelopes.