ENEL 390

AM Modulation & Demodulation Project

Arpan Dhamane

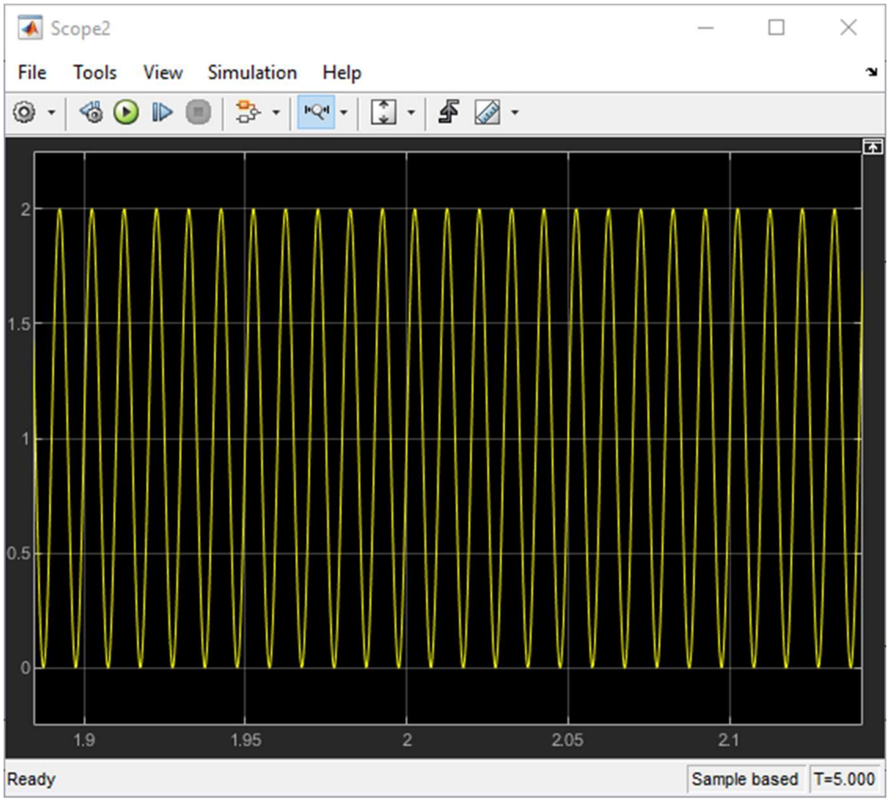
Introduction:

This project is about the relationship between the modulation index, efficiency and distortion of a DSB-FC signal. By using the SIMULINK program, we can build both an AM modulation and demodulation simulation. The SIMULINK library provides a multitude of tools such as Scopes, Spectrum Analyzers, Filters, Signal Generators and much more. An analysis can be made about the effects on the difference in the modulation index of a signal and what value would provide the optimal distortion less signal with the best efficiency. The discussion portion explains the relationships and theory between the three mathematical terms.

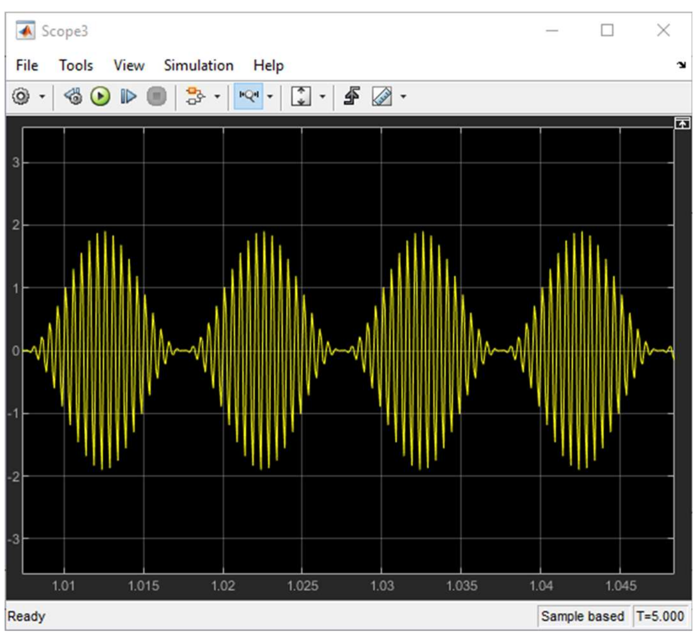
Analysis:

Index of 1:

Let’s take a 100 Hz sine signal as an example for a tone message signal with a DC offset of 1:



We can then place that message signal through a multiplier with a sine carrier signal of 2 kHz:



$g(t) = \sin(2*pi*100*t) * \sin(2*pi*2000*t)$

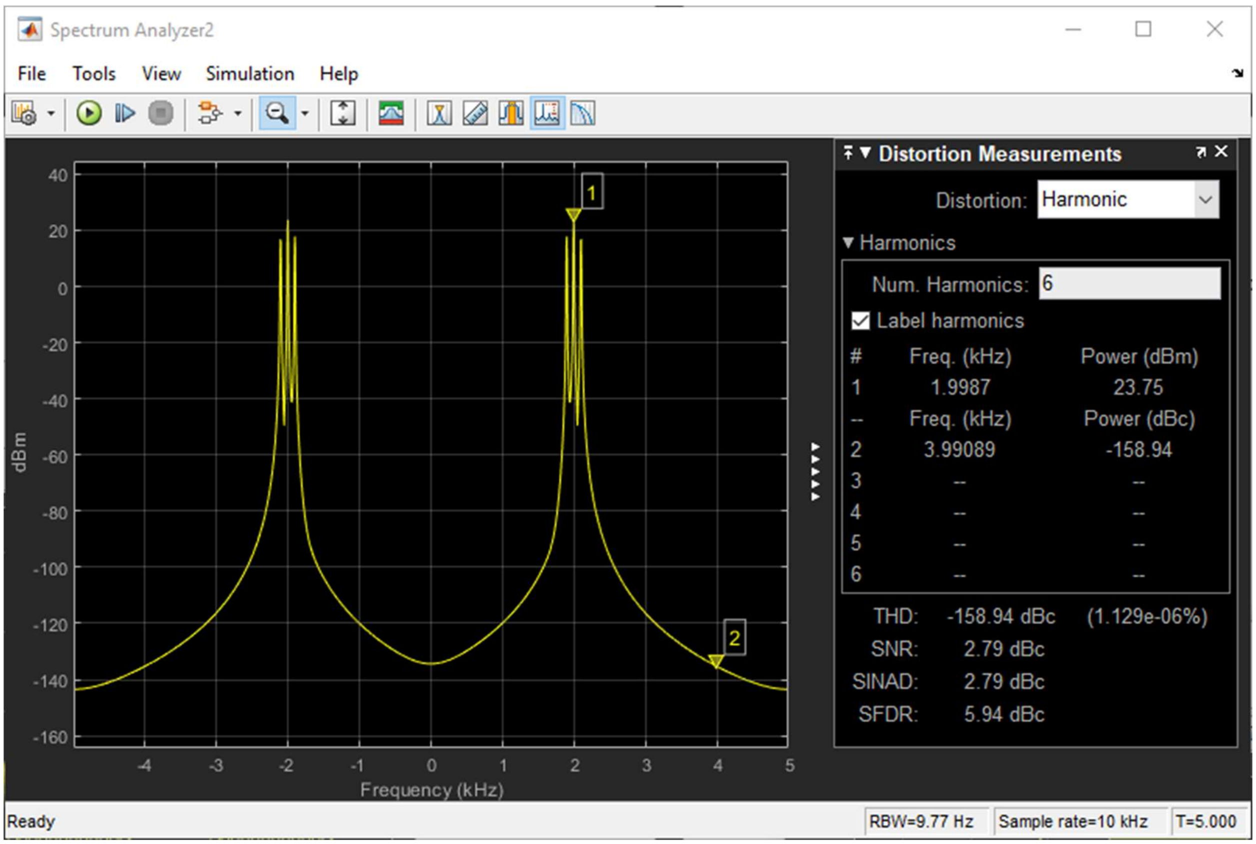
$G(f) = (\frac{1}{4})[\delta(f + 1900) + \delta(f - 1900) - \delta(f + 2100) - \delta(f - 2100)]$

LSB & USB: -2100 to -1900 & 1900 to 2100

m(Modulation Index) = b/A = 1/1 = 1

Bandwidth modulating signal = $2*fm$ = 200 Hz

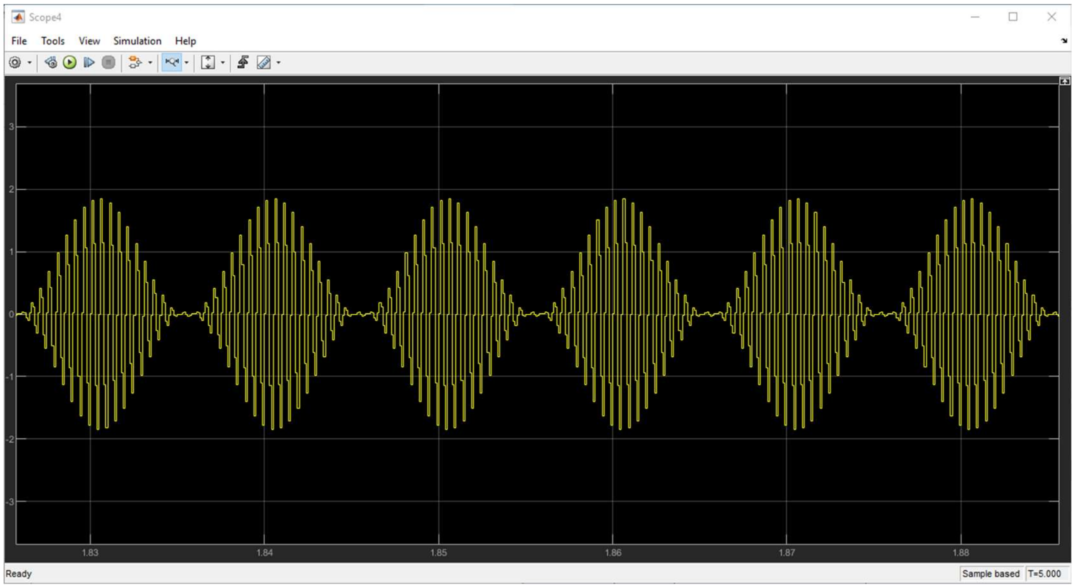
We can see the power in the sidebands and carrier by using a spectrum analyzer:



n(efficiency) = $(((m*A)^2)/2)/((A^2)+(((m*A)^2)/2)) * 100\%$ = 33%

given m = 1, for tone modulation n is at max of 33%

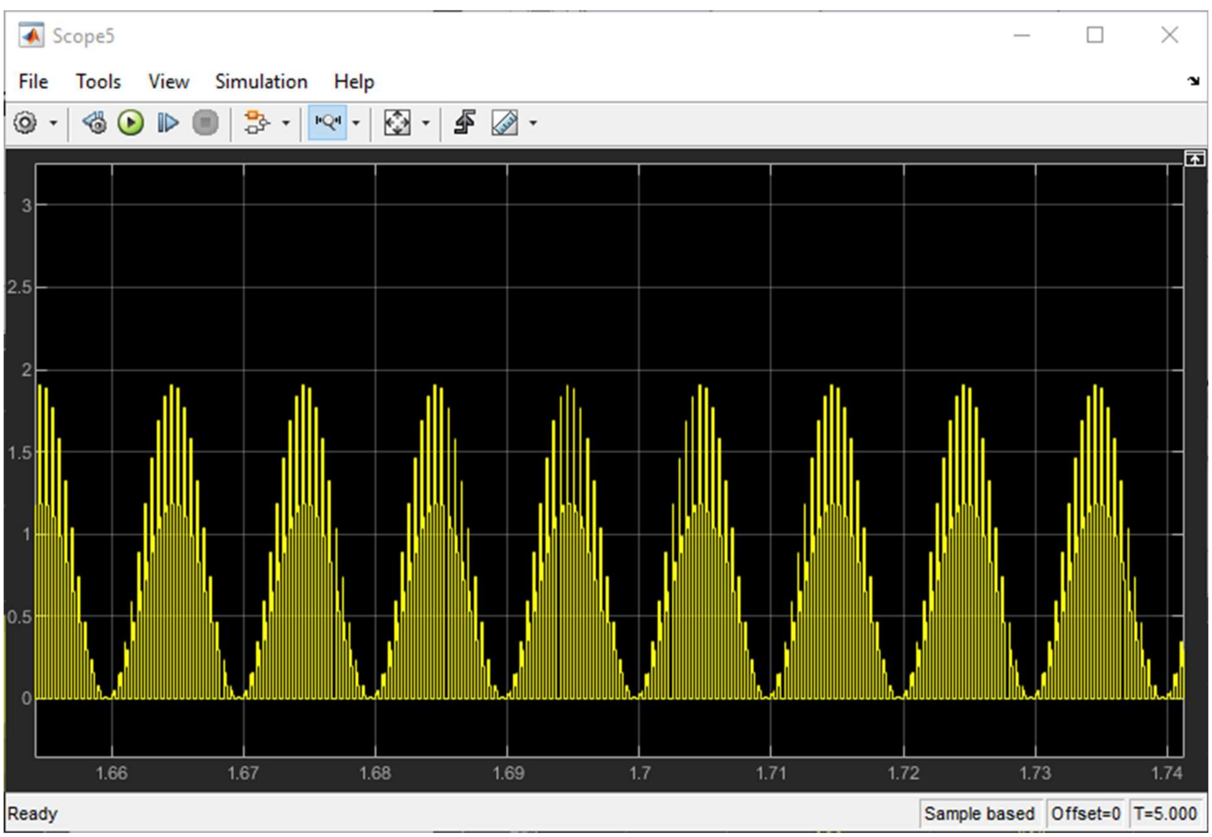
We can use a bandpass filter centered at the carrier frequency to get the desired modulated signal:



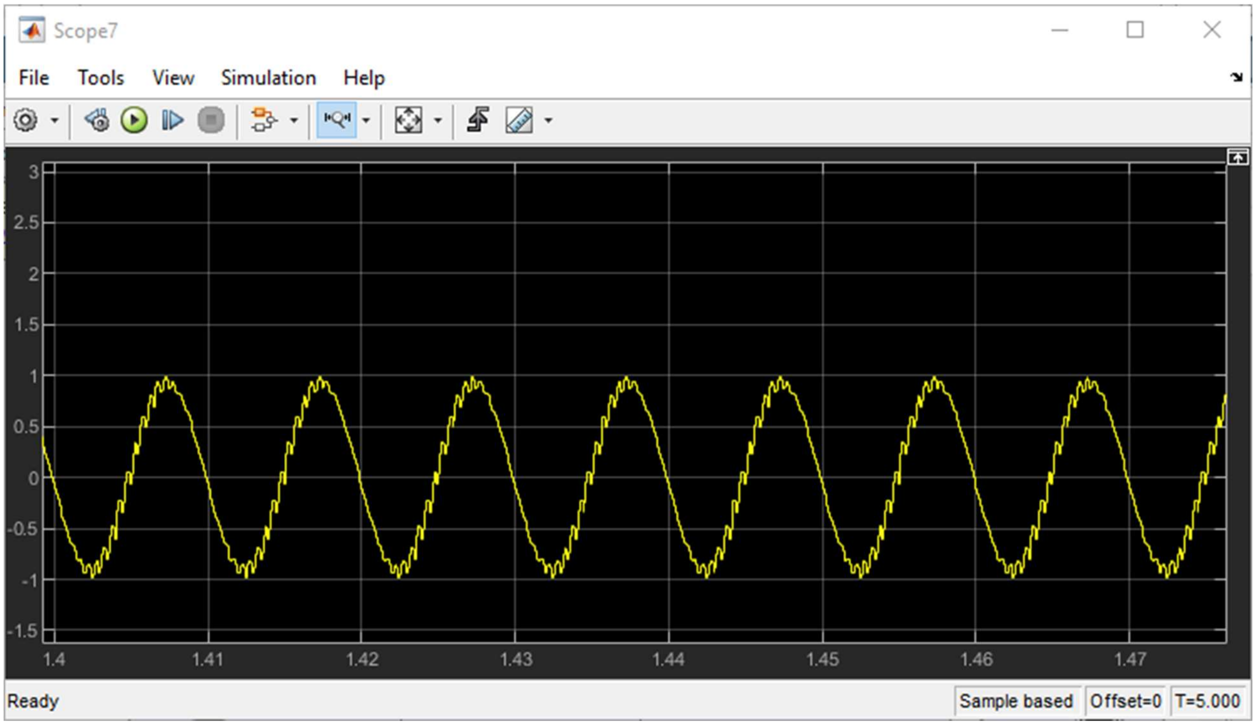
Passband frequency 1 & 2 = (2100 - 1000 - 150) & (1000 + 2100 + 150) = 950 Hz & 3250 Hz

Stopband frequency = passband1 - fm & passband2 + fm = 850 Hz & 3350 Hz

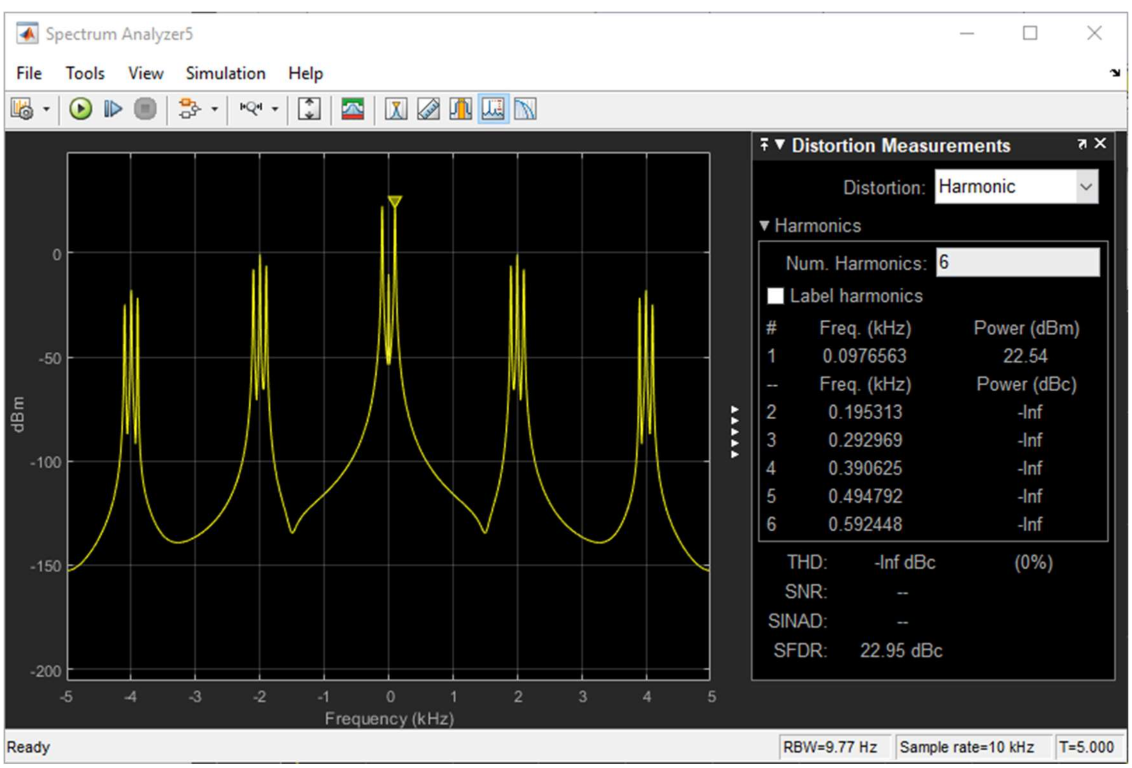
We can take this modulated filtered signal and rectify it with a diode rectification (in this case a periodic pulsed square wave) of the same frequency as the carrier signal:



Finally, we can use a Lowpass filter, a DC Blocker and a gain of 2.5 to demodulate the signal from the rectification to the message signal of 100 Hz:



Frequency of final demodulated signal: 97.7 Hz - approx. 100Hz



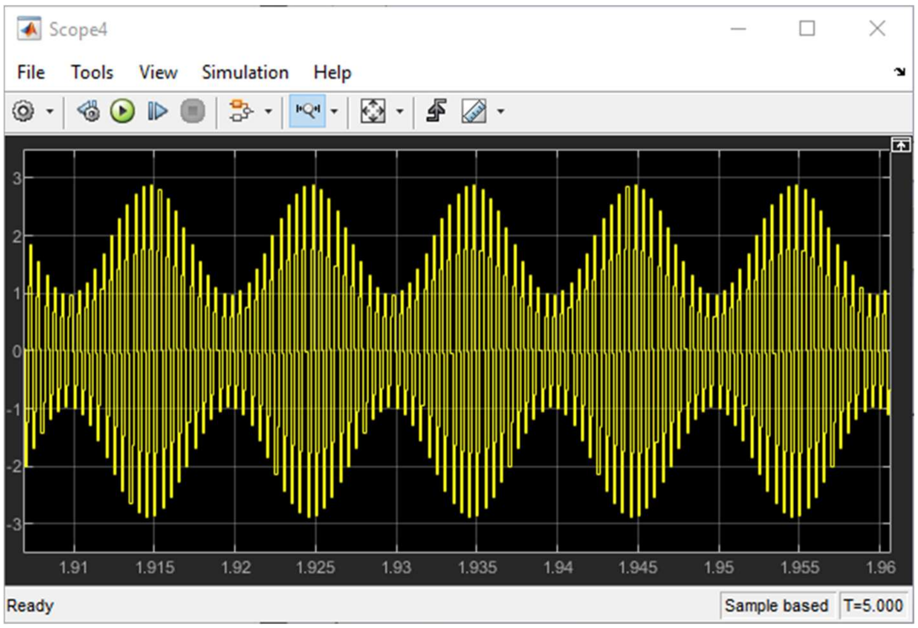
Different Indexes:

Now we can repeat the process with two different modulation indexes:

m at 0.5, then n = 11%

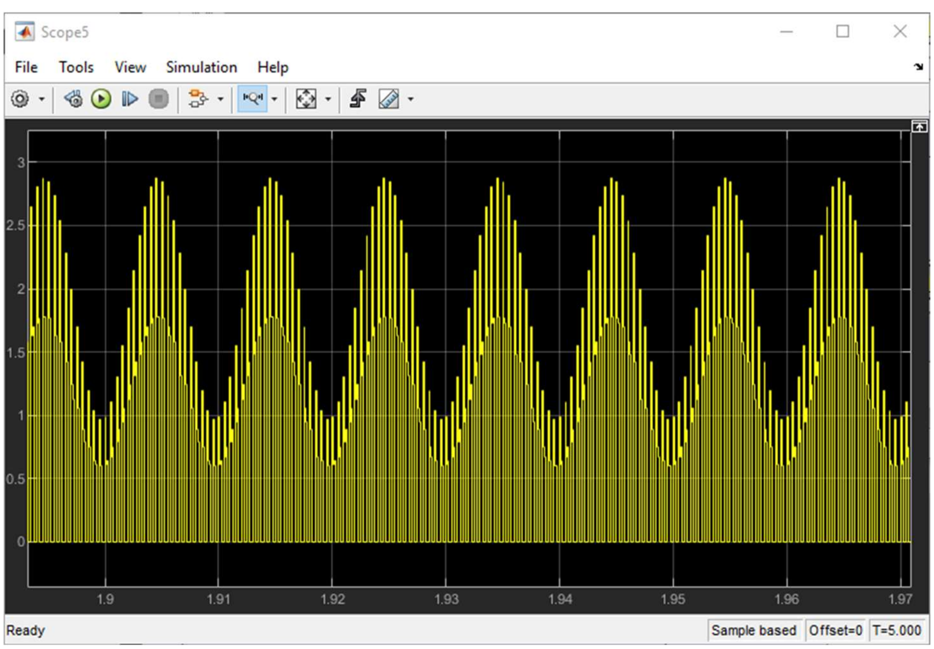
m at 1.5, then n = 53%

m=0.5:

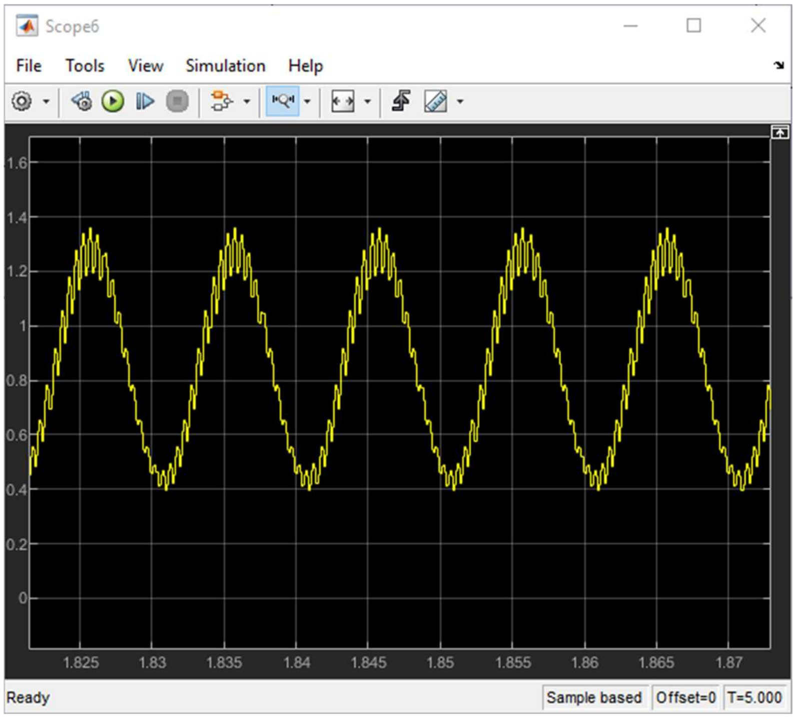


We do not see any distortion in the modulated signal, but a bit of distortion during the demodulating phase.

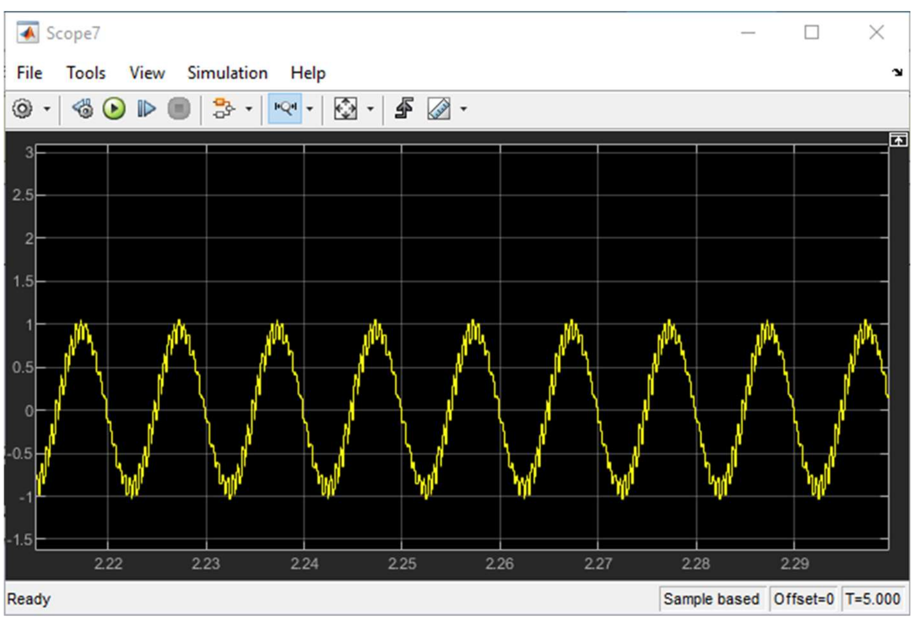
After diode rectification:



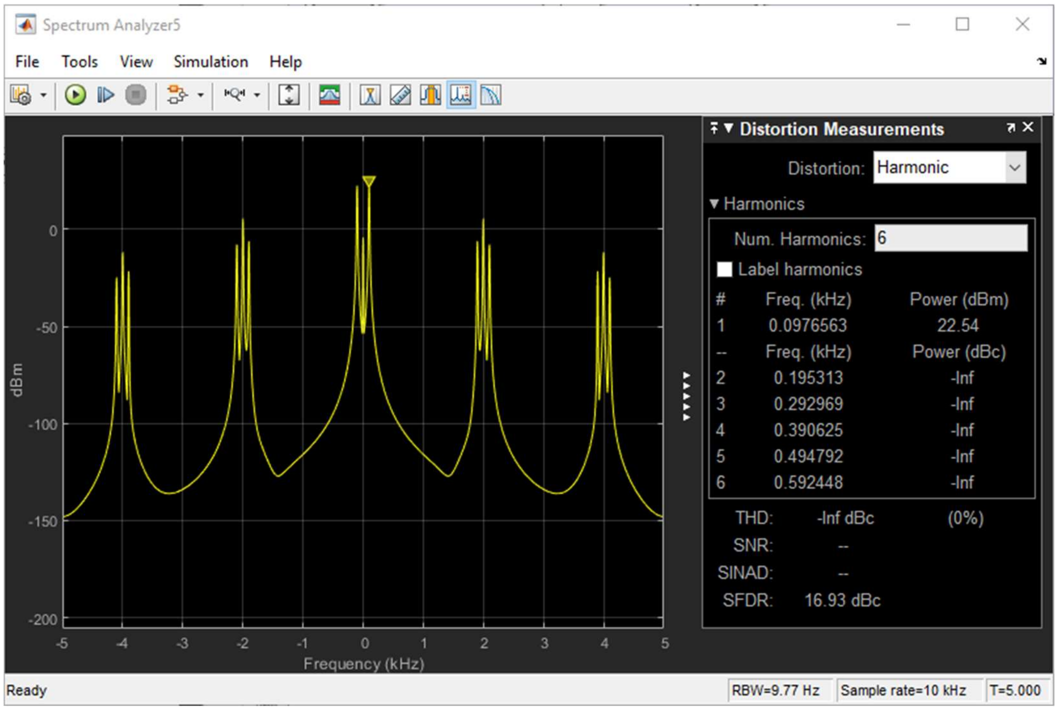
LPF Output:



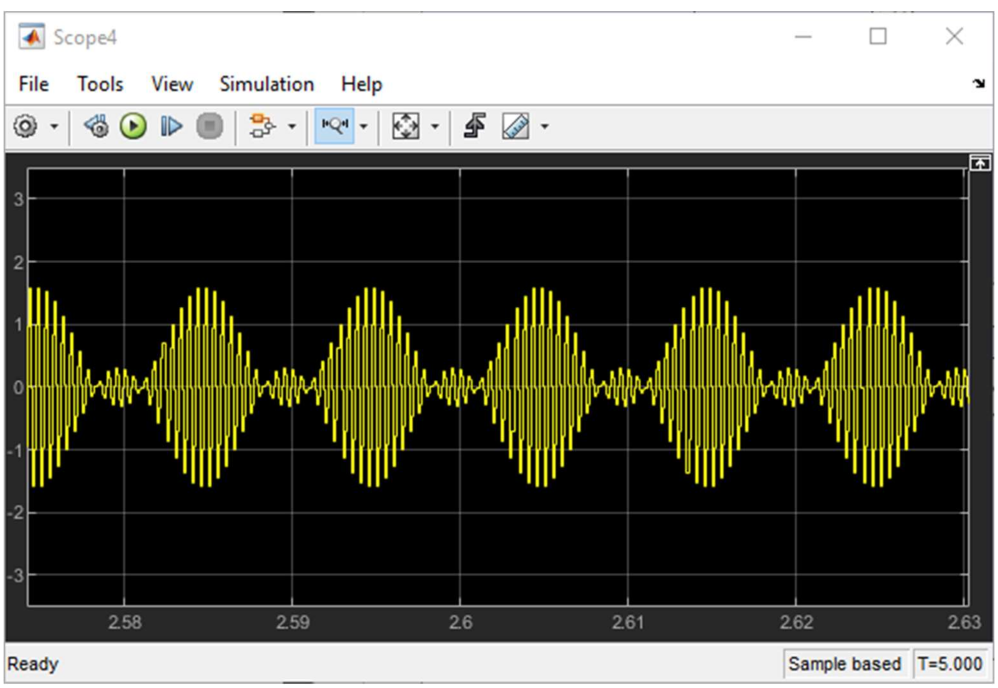
Final demodulated message:



Frequency and Power:

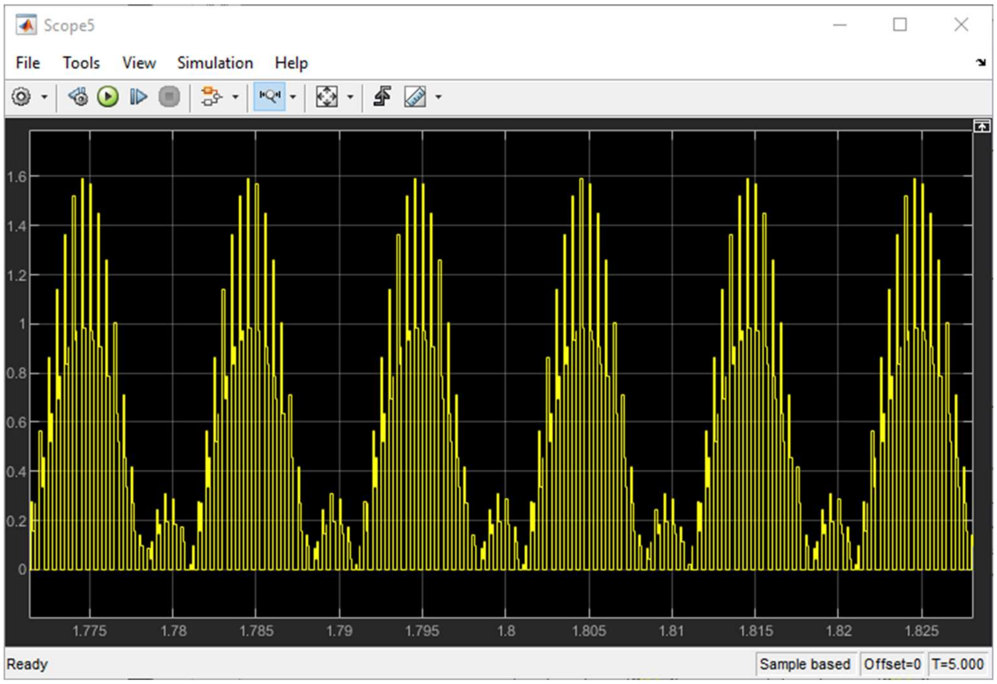


m=1.5:

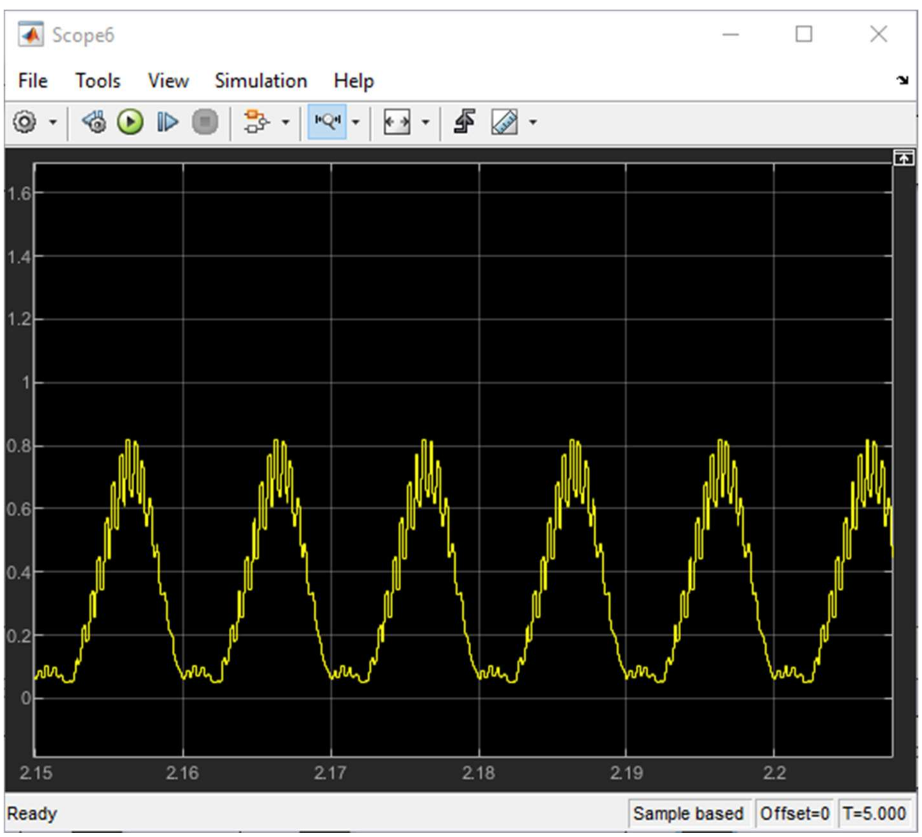


When the modulation index goes above 1, the signal is overmodulated and causes significant distortion in the signal.

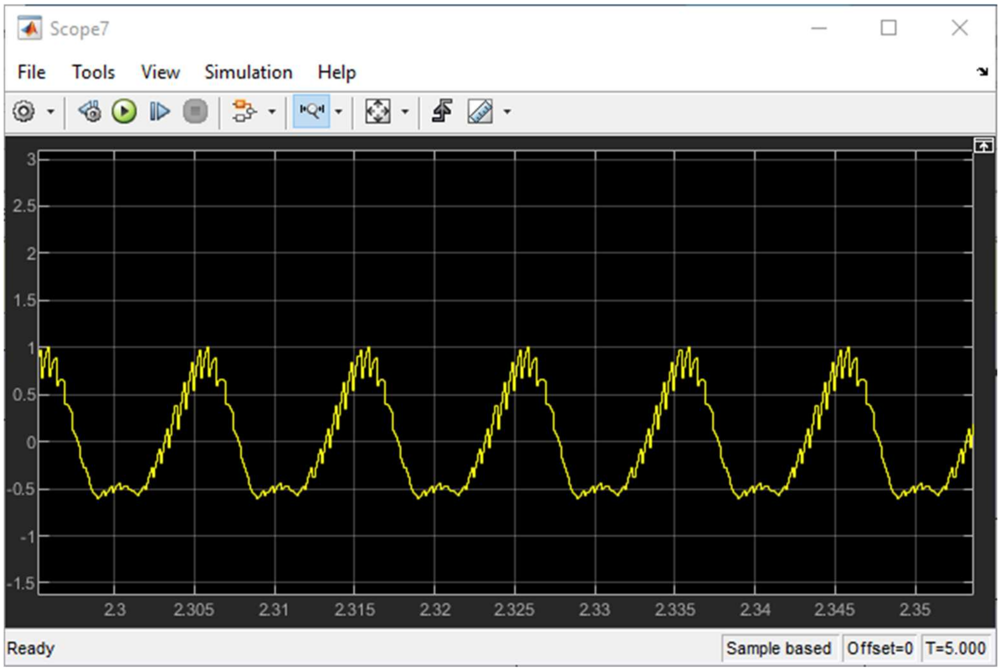
After diode rectification:



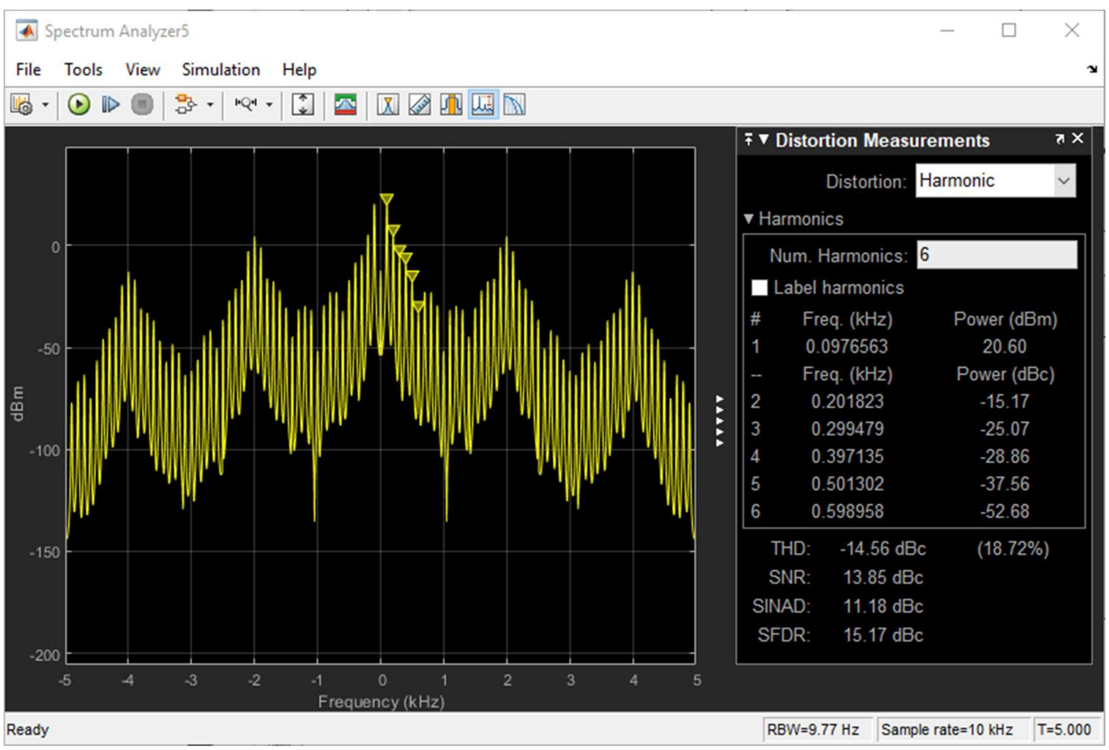
LPF Output:



Final demodulated message:



Frequency and Power:



Discussion:

As we can see from the Analysis, the modulation index of 1 and 0.5 give us a modulated signal and demodulated signal without any significant distortion. Once the index goes over the value of 1, we get an increasing amount of distortion. At the index of 1.5, we can see how the modulated signal is overlapping and creating significant distortion. After demodulation, the 1.5 index signal is different from the message signal, where the waveform after the diode rectifier does not look like a sine waveform. We can follow the edge of the rectified signal on the scope to determine the wave form shape. From the calculations, we can see that the 1.5 index signal is more efficient but does not give the original message signal after demodulation. Whereas the 1 and 0.5 index signals are less efficient (n max at 30% in tone modulation when m = 1), except they provide the desired output to the receiver with minimal distortion.

Looking back at the DC offset, when the value is high, there is less efficiency and vice versa. The draw backs of a smaller DC offset, creates more distortion for the modulated and demodulated signal due the index equation m = b/A, where m is the modulation index, b is the value in front of the carrier + message waveform, and A is the amplitude of the carrier + message waveform.

The value of tau was set to [1/(2*pi*fc)] = 0.000796 seconds because fc would be the passband edge frequency of the LPF valued at 200 Hz. We will also achieve a fast response from the filter. R can be assumed to be a 1 M Ohm resistor with C at 7.96E-10 Farads. The optimal value for m is 1 because we get an almost distortion less modulated signal with the max efficiency for a tone modulation. The bandpass filter calculations were done to retain more than 90% of the energy of the modulated signal.

In one of the references, the output after the diode rectifier demodulation is almost no difference from the simulation. There is some distortion on the upper curve of the demodulated waveform in the (ENEL 390 Lab 4) video and the simulation does show the same distortions. The reason for that to occur is due to the signal that is acting as the diode portion from the video. That signal is a periodic pulsed square wave in the simulation. The absolute block function acts as an inverter for all negative samples. This helps us get the rectified wave form as shown in lab 4 of ENEL 390.

Conclusion:

The simulation completed on SIMULINK, proves the theory of AM modulation and demodulation, while explaining the relationship between the modulation index, efficiency and distortion of a DSB-FC signal. More complex tones/input waves can be used to demonstrate how AM modulation and demodulation can be accomplished using a variety of Simulink tools.

References:

Urcourses:

https://urcourses.uregina.ca/pluginfile.php/2114934/mod_resource/content/1/project%20hint.pdf

https://urcourses.uregina.ca/pluginfile.php/1566689/mod_resource/content/1/Chapter%204%20%28notes%20from%20BP%20Lathi%29.pdf

Dave Duguid:

https://www.youtube.com/watch?v=mmpZMpflyi8&feature=youtu.be