Communications Lab
Experiment 1
Lab Report

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<u>Amplitude Modulation</u>:

As the name suggests Amplitude Modulation is the communication technique wherein the message resides within the amplitude variations of the modulated signal.

There are 3 most common modulation techniques to implement AM:

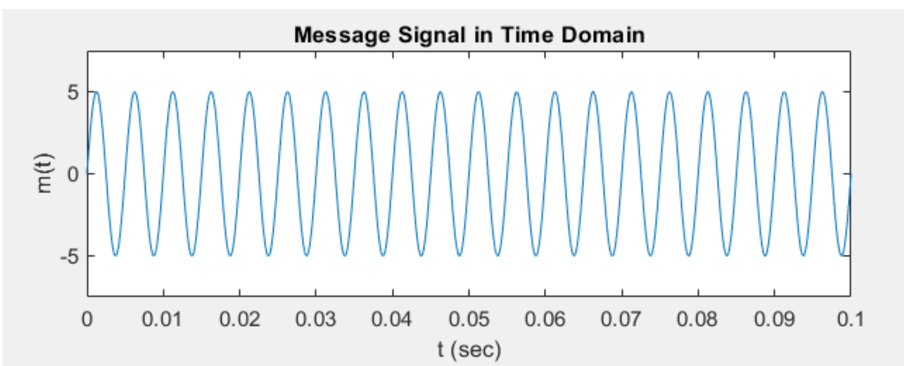
1) **DSB-SC (**Double SideBand-Suppressed Carrier**):**
   DSB-SC is the easiest AM technique, in this we just multiply our message with the carrier wave. passband transmitted signal is of the form:

$$U(t) = m(t)\cos(2\pi f c t)$$

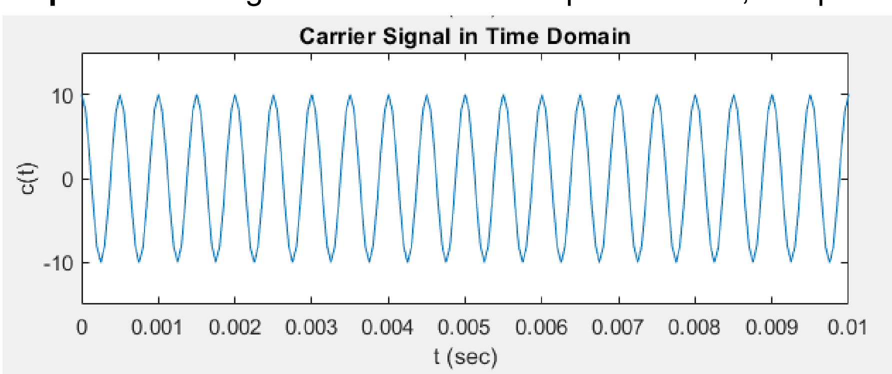
<u>DSB-SC simulation on matlab:</u>

Code attached - DSB_SC.m

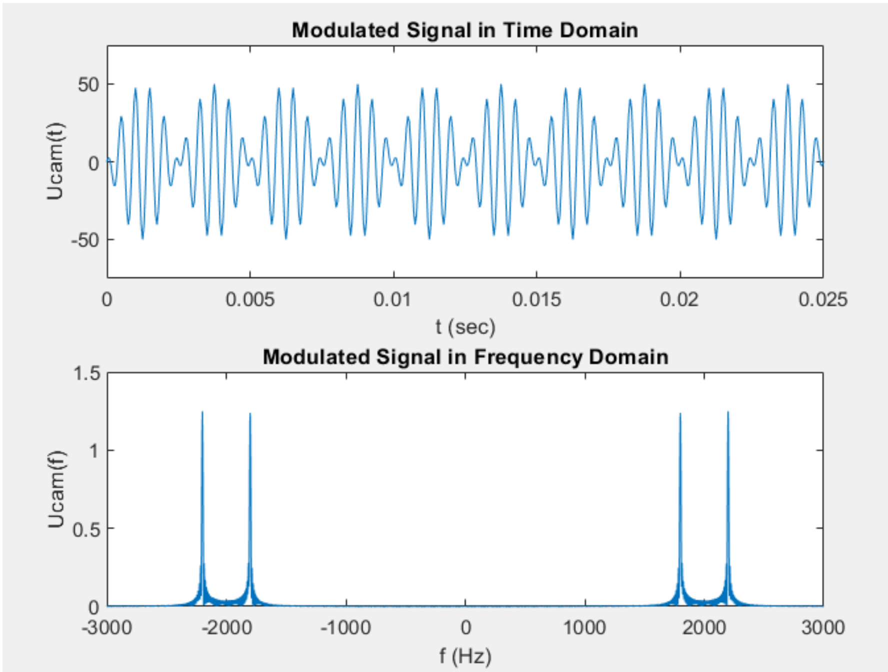
Step1: Generating the message signal. Amplitude = 5 , Frequency = 200Hz



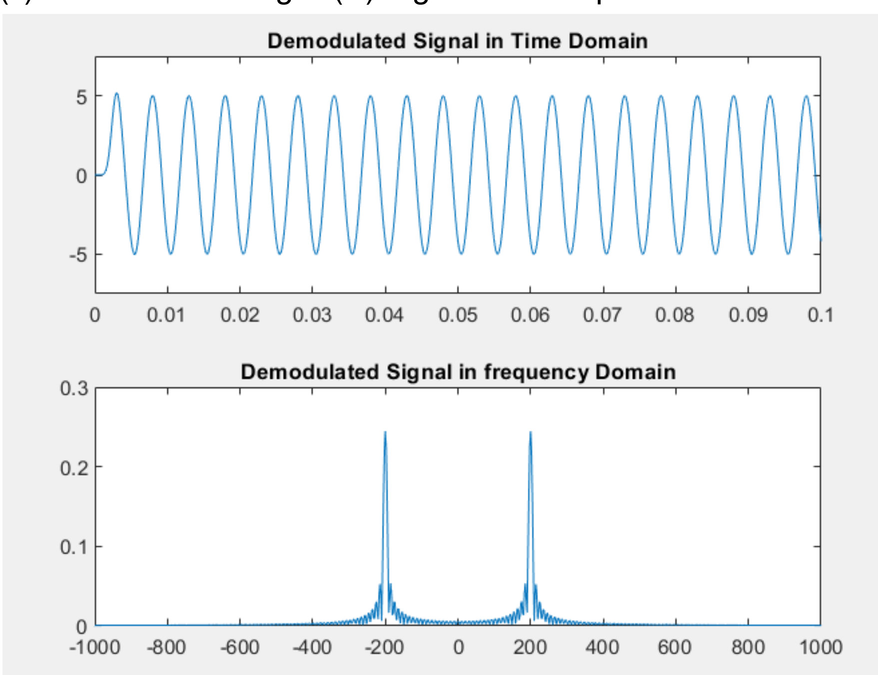
Step2: Generating the carrier wave. Amplitude = 10 , Frequency = 2000Hz



Step3: Modulation. The modulated signal is nothing but the product of the message signal and the carrier wave.



Step4: Demodulation, it is a three step process.(i) Multiplication with carrier wave (ii) Low Pass filtering & (iii) Algebraic manipulation.



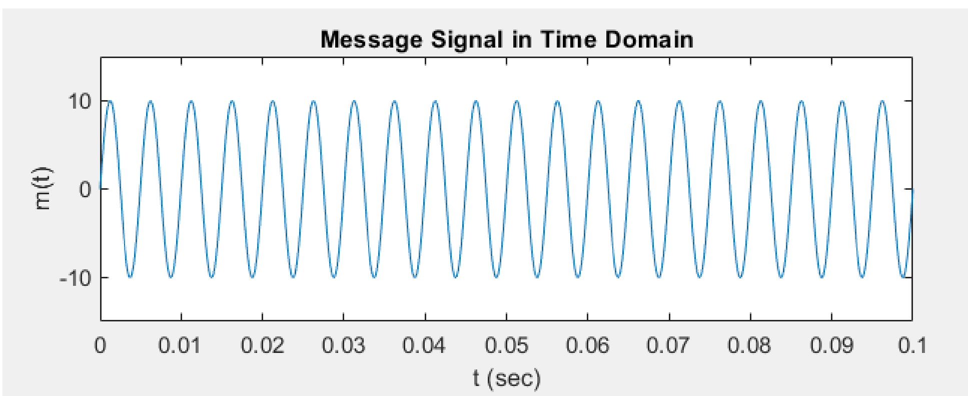
Observations:
i) We can see that the Modulated signal has 4 peaks in the Frequency domain which is intuitive as the modulation technique is Double SideBand-Suppressed Carrier
ii) The Demodulated Signal has some irregularities in amplitude for the first half cycle and a slight phase shift overall.

2) **Conventional AM**:
In conventional AM, we add a large carrier component to a DSB-SC signal, so that the passband transmitted signal is of the form:

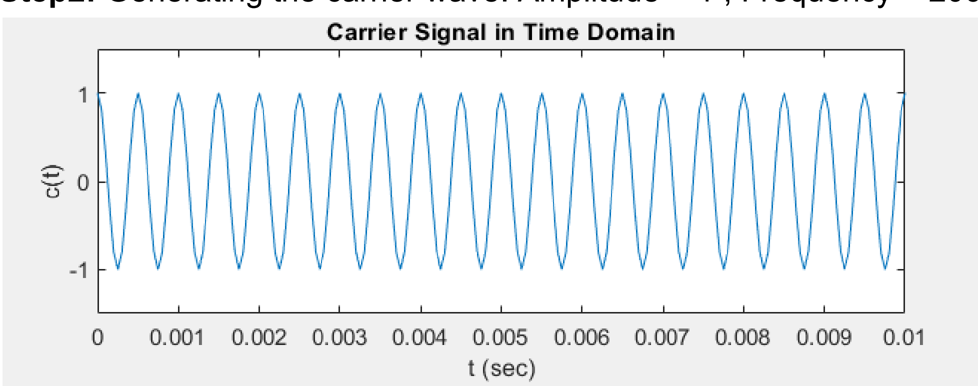
$$U(t) = m(t)\cos(2\pi fct) + Ac \cos(2\pi fct)$$

As we have a large carrier component, conventional AM is not Suppressed carrier modulation.

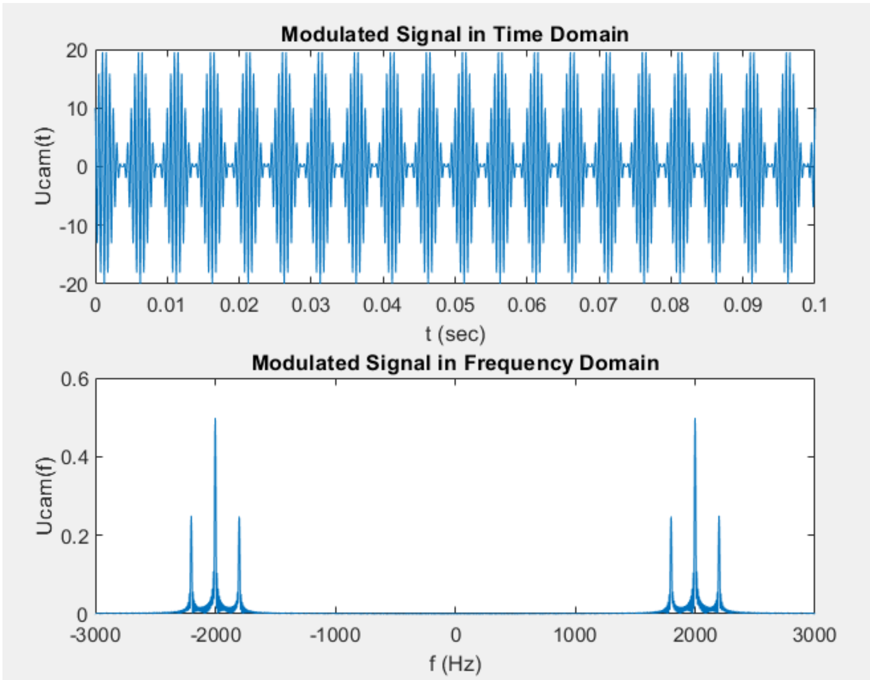
Conventional AM simulation on matlab:
Code attached - ConventionalAM.m
Step1: Generating the message signal. Amplitude = 10 , Frequency = 200Hz



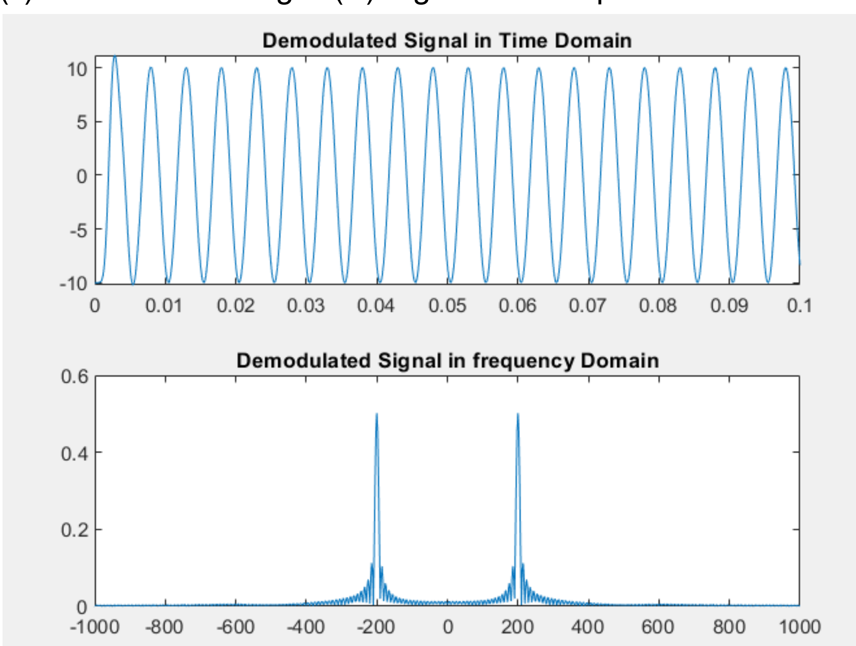
Step2: Generating the carrier wave. Amplitude = 1 , Frequency = 2000Hz



Step3: Modulation. Multiplication of message with carrier followed by addition of a large carrier component.



Step4: Demodulation, it is a three step process.(i) Multiplication with carrier wave (ii) Low Pass filtering & (iii) Algebraic manipulation.



Observations:

i) We can see that the Modulated signal has <u>6 peaks</u> (4 for message & 2 for carrier) in the Frequency domain as Conventional AM is DSB without suppressed carrier.

ii) The Demodulated Signal has some irregularities in amplitude for the first half cycle and a slight phase shift overall.

3) **<u>SSB-SC:</u>(**Single SideBand suppressed carrier**)**

In SSB modulation, we send either the upper sideband or the lower sideband of a DSB-SC signal. This is done by multiplying the hilbert transform of the message signal with the Q component of the carrier and adding/subtracting it from the DSB-SC modulated signal. The passband transmitted signal is of the form:

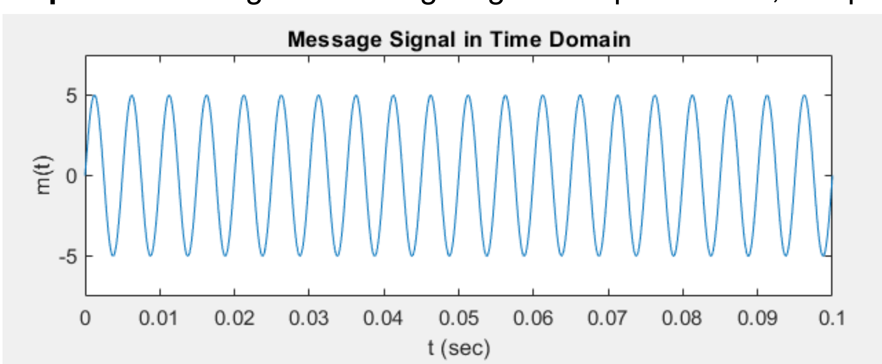
$$U(t) = m(t)\cos(2\pi fct) \pm \acute{m}(t)\sin(2\pi fct)$$

We add the Q component when we consider the Lower SideBand(LSB), whereas we subtract the Q component when we consider the Upper SideBand(USB).

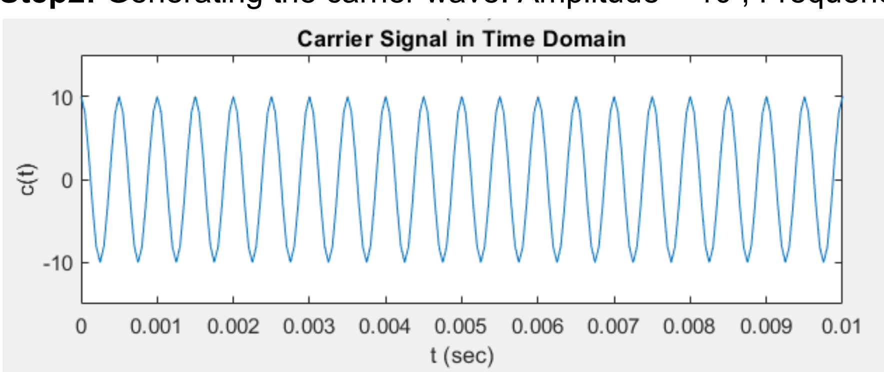
<u>SSB-SC simulation on matlab:</u>

Code attached - SSB_SC.m

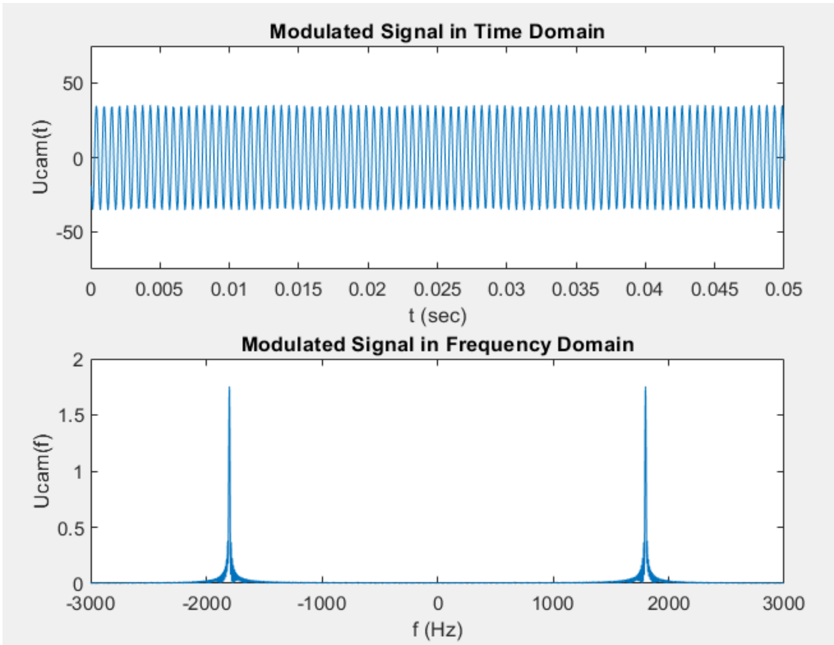
Step1: Generating the message signal. Amplitude = 5 , Frequency = 200Hz



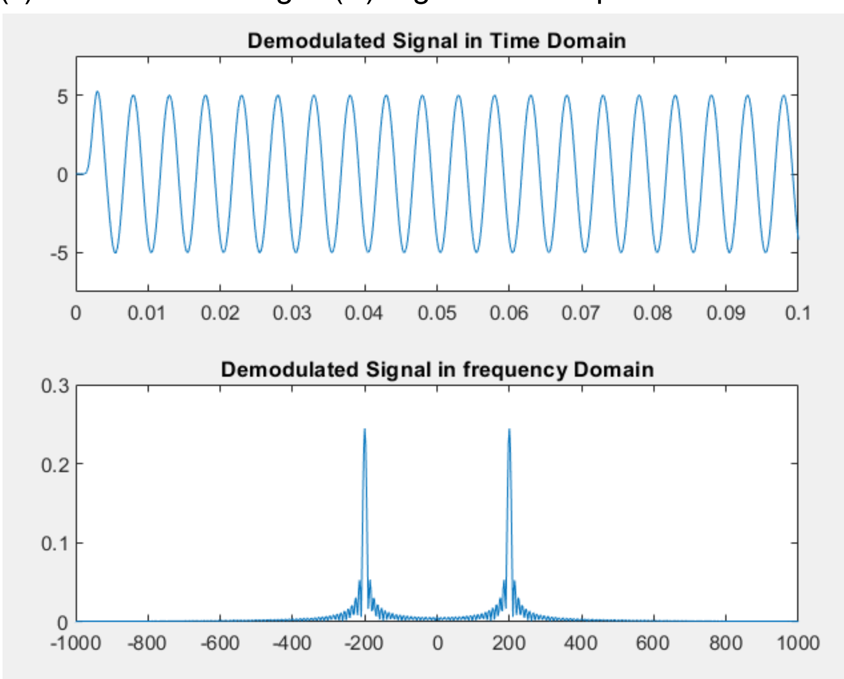
Step2: Generating the carrier wave. Amplitude = 10 , Frequency = 2000Hz



Step3: Modulation, Multiplication of message with carrier followed by addition of the product of Q-component of carrier and Hilbert transform of message.(we are considering LSB)



Step4: Demodulation, it is a three step process.(i) Multiplication with carrier wave (ii) Low Pass filtering & (iii) Algebraic manipulation.

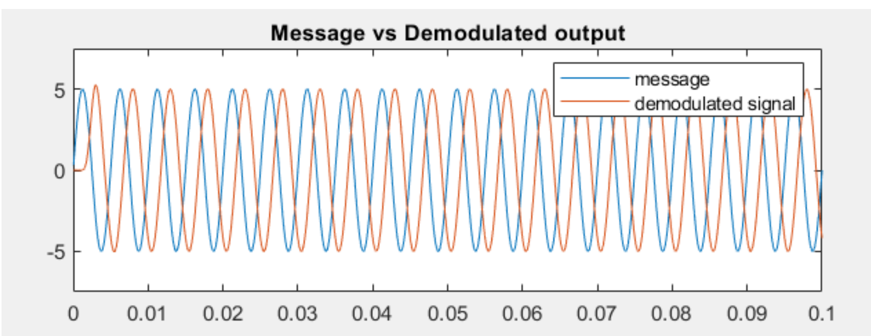


Observations:
i) We can see that the Modulated signal has only 2 peaks in the Frequency domain as SSB-SC only has a single sideband with suppressed carrier.
ii) The Demodulated Signal has some irregularities in amplitude for the first half cycle and a slight phase shift overall.

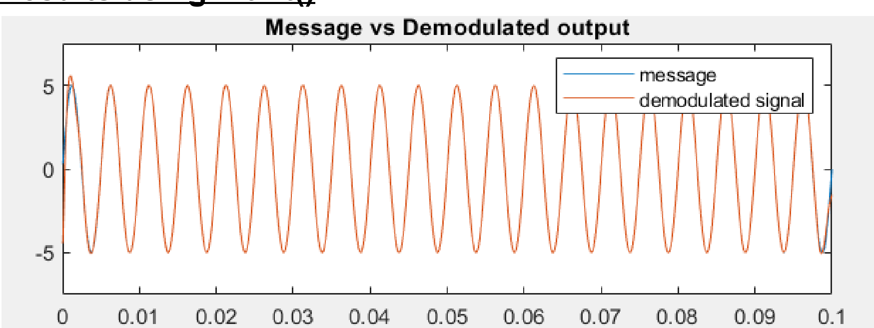
Final Conclusions:
We observed some irregularities in amplitude in the first half cycle and a slight phase shift overall in the demodulated message signal for all the 3 modulation techniques. These irregularities are caused because the low pass filters are not ideal.

Filtering a signal introduces a delay. This means that the output signal is shifted in time with respect to the input.
Sometimes the filter delays some frequency components more than others. This phenomenon is called phase distortion. To compensate for this effect, we can perform zero-phase filtering using the **filtfilt** function.

Actual Results(using filter()):



Results using filtfilt():



We can see that although filter() and filtfilt() both remove the high frequency noise, the use of filter() introduces significant phase delay. filtfilt() has zero phase delay. Further, at t=0, the output of filter() starts at 0, whereas the output of filtfilt() has matched the initial conditions exactly.
filter() provides a real time simulation of the filtering process whereas filtfilt() is just a theoretical way of filtering.Hence I have used filter() in my simulation.