BERZIET UNIVERSITY

FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ENEE 4113

communication Laboratory.

Experiment 2

DSB Modulation and Demodulation

Prepared by: Anas Nimer 1180180

Instructor: Dr. mohammad jubran

TA: Eng.Ruba Eid

Section # : 3

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1. Abstract :

The main objective of this experiment centralizes about studying Single Sideband Suppressed Carrier Modulation (SSB-SC). In addition, the characteristics of each type was studied such as: The modulation technique, the behavior of the modulated signal in time and frequency domain and the demodulation technique. An explanation and analysis of each type is presented in this report.

Continent:

Table of figure:

2. Procedure:

2.1 DSB-SC modulation in the time and frequency domains:

2.1.1 Equation and result without any change:

In DSB-SC, the formula of the modulated signal is shown below:

$s(t)=A_c\, m(t) \cos(2\pi f_c t)$

Where:

S(t): The modulated signal.

m(t): The modulating signal (message signal).

A_c: The amplitude of the carrier signal.
f_c: The frequency of the carrier signal.

Let :

```
Am=1 # amplitude of message signal
fm=1000 # frequency of message signal
Ac=1 # amplitude of carrier signal
fc=10000 # frequency of carrier signal
```

$m(t)=1.\cos(2\pi(1000)\, t)$

$c(t)=1.\cos(2\pi(10000)\, t)$

$s(t)=1.1.\cos(2\pi(1000)\, t).\cos(2\pi 10000 t)$

The signals were plotted in time and frequency domain as shown in fig below

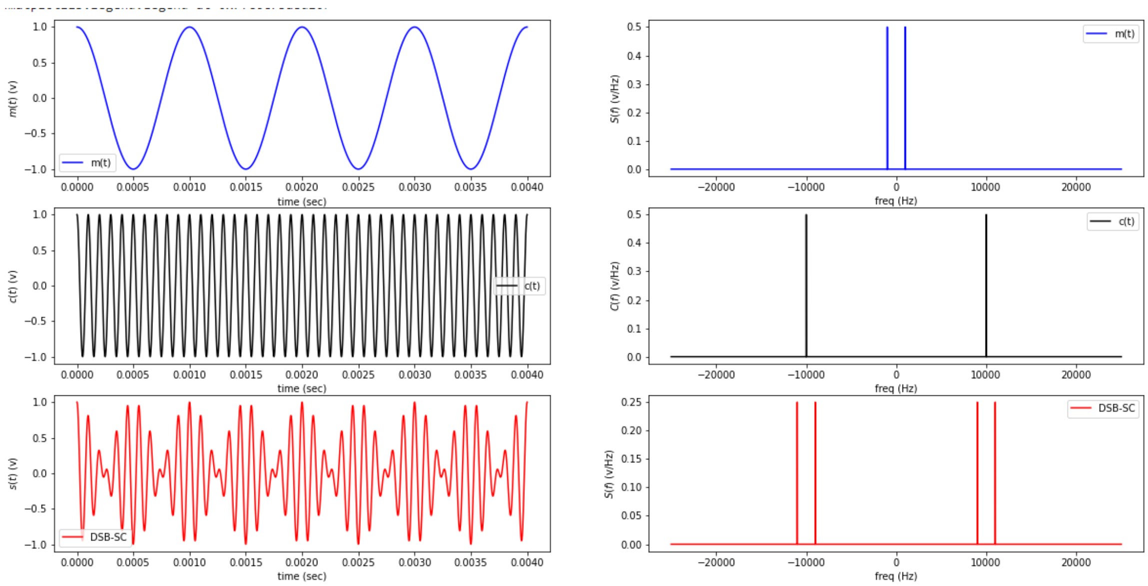

Figure 1: m(t), c(t), s(t) in time and frequency domain

- **<u>Note</u>**: We notice 3 signal in the above figure, m(t) -massage- ,c(t) - carrier - each with a different shape, amplitude and frequency. S(t) – DSB modulation signal- signal That depend on m(t) and c(t).

envelope detector could not be used in DSB because only the upper and lower side of the signal are transmitted without the carrier as shown in previous figure.

2.1.2 **Exercise:**

The parameters of the signal were varied as following

2.1.2.1 **fm = 500 Hz :**

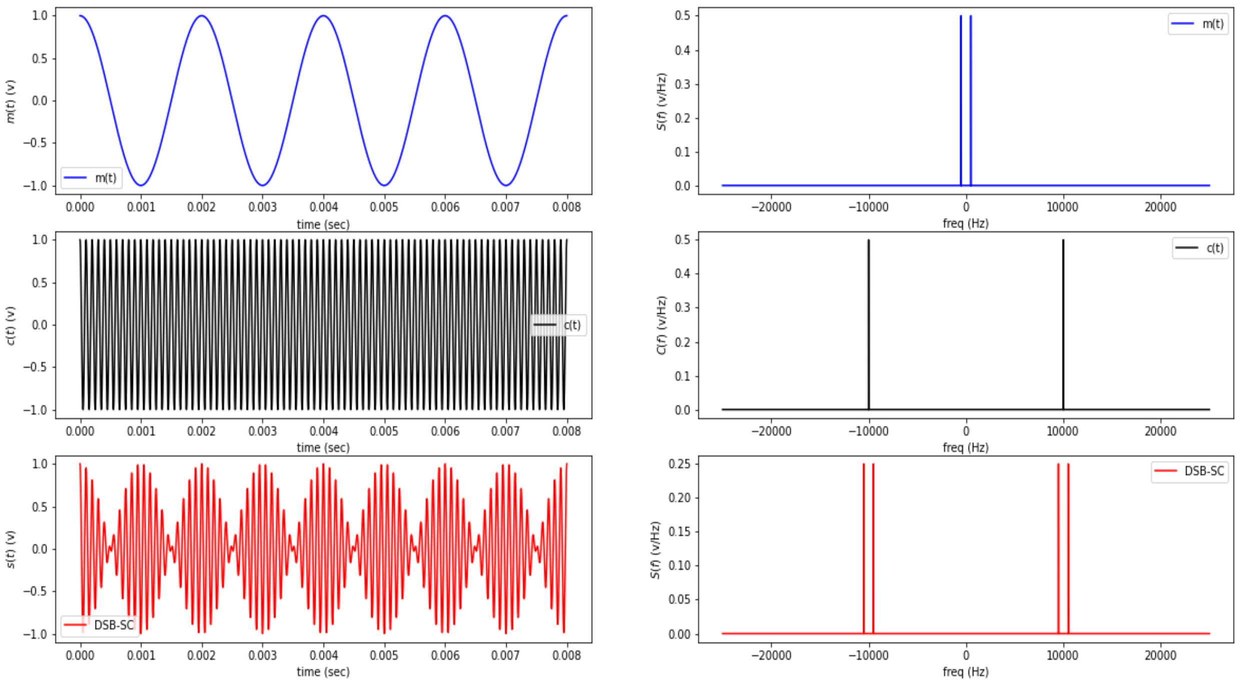

Figure 2:m(t), c(t), s(t) in time and frequency domain with fm = 500

- **Note:** when fm was decreased/increase the envelop and frequency for carrier signal were not affected. . but envelop for massage and DSB signal waves envelop close together if deceased or move away from each other if increases. in addition to the DSB signal frequency changed by
  (fc-fm , fc+fm) =>(10000-500, 10000+500)
  (-fc-fm , -fc+fm) =>(-10000-500,-10000+500)
  But their amplitude were not affected.

2.1.2.2 **fc=5000 Hz :**

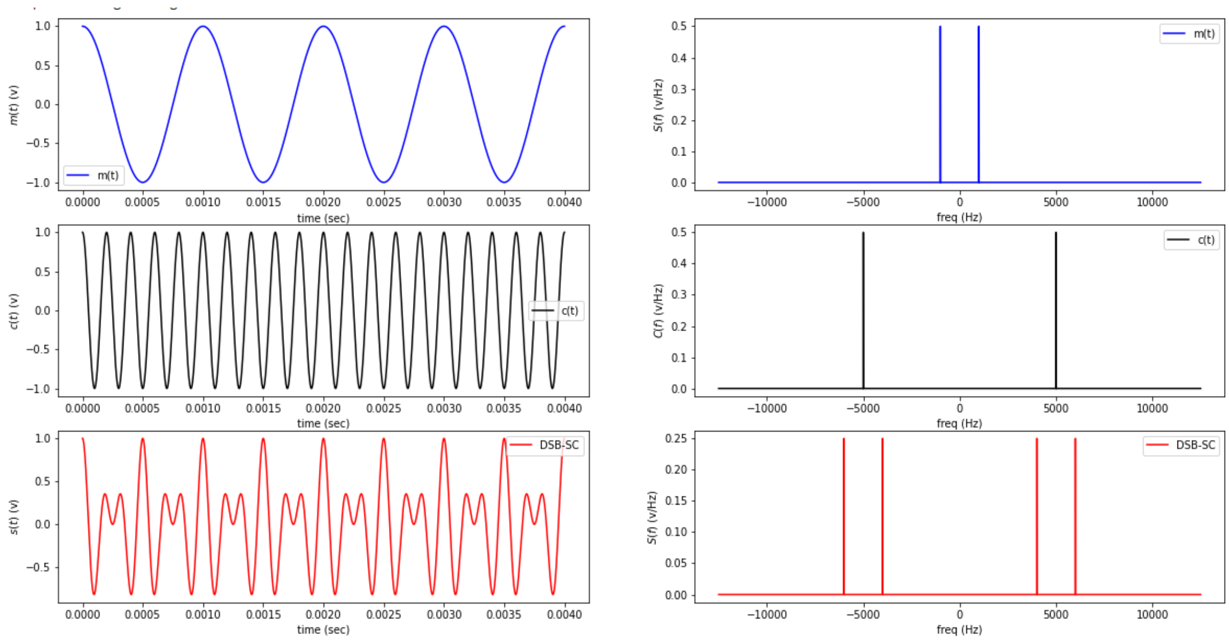

Figure 3: m(t), c(t), s(t) in time and frequency domain with fc = 5000

- **Note:** when fc was decreased/increase the envelop and frequency of massage signal were not affected . but envelop for carrier and DSB signal waves expand and move away from each other if decreased or close together if increase. And the DSB signal frequency changed by :

  (fc-fm , fc+fm) =>(5000-1000 , 5000+1000)

  (-fc-fm , -fc+fm) =>(-5000-1000 , -5000+1000)

  But their amplitude were not affected.

2.1.2.3 **<u>Am = 2 :</u>**

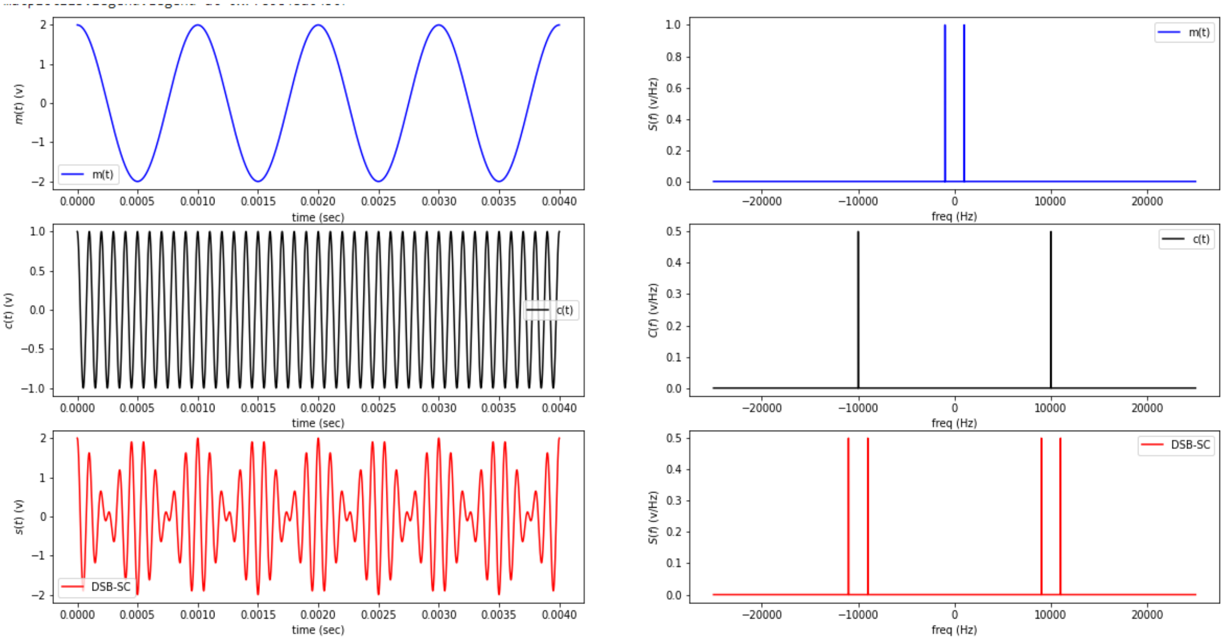

Figure 4:m(t), c(t), s(t) in time and frequency domain with Am = 2

- **<u>Note</u>:** when Am increased/decrees the peak of the massage increases/decrees and DSB signals envelope amplitude increases/decrees by (Am.Ac), While in frequency domain the amplitude of frequency change by ((Ac.Am) / 2), But the site that followed is not affected. in addition to, massage amplitude frequency value changes by (A_m/2), but the carrier envelop and frequency were not affected.

2.1.2.4 Ac = 2 :

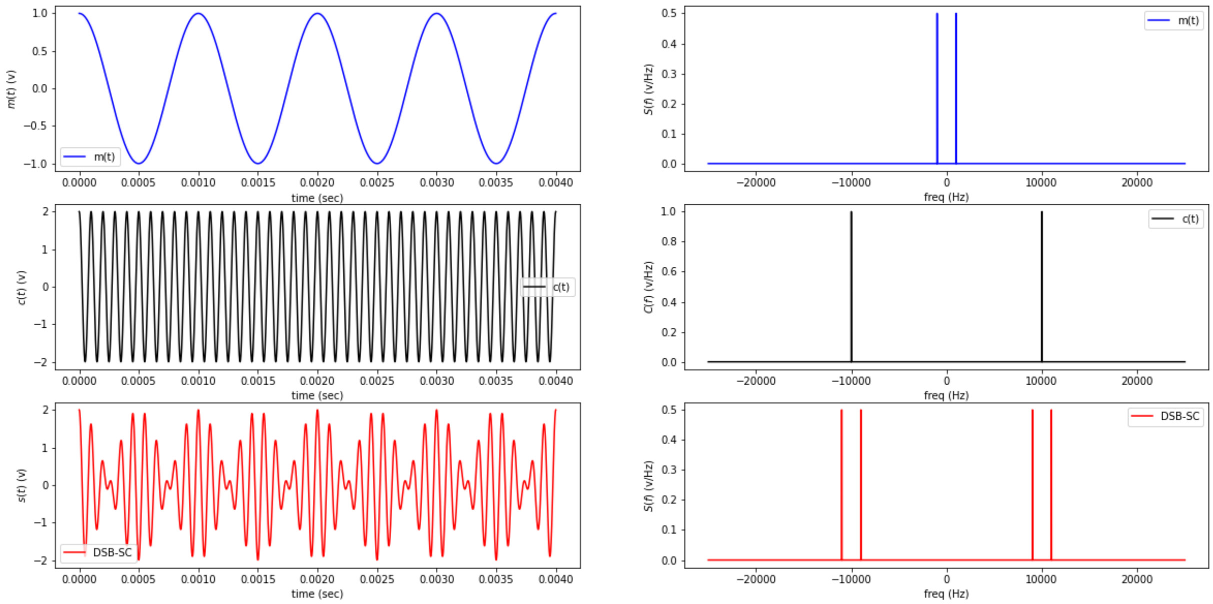

Figure 5: m(t), c(t), s(t) in time and frequency domain with Ac = 2

- **Note:** when Ac increased / decrease the peak of the carrier increases / decrease and DSB signals envelope amplitude increases / decrease by (Am.Ac) , While in frequency domain the amplitude of frequency change by ((Ac.Am) / 2), But the site that followed is not affected . in addition to, carrier amplitude frequency value changes by (A_c/2). But the massage envelope and frequency doesn't change.

2.2 DSB-SC modulation of a message signal with multiple harmonics:

2.2.1 Equation and result without any change:

$$f(t)=A_{m1}\cos(2\pi f_{m1}t)+A_{m2}\cos(2\pi f_{m2}t)+A_{m3}\cos(2\pi f_{m3}t)$$

where:

f(t): sum of 3 cos.

$Am_{1,2,3}$: amplitude of message signal.

$Fm_{1,2,3}$: frequency of message signal.

$$S(f) = (Am_1.\ Ac/2)\cos(2\pi(f - fm_1)t) + (Am_1.\ Ac/2)\cos(2\pi(f + fm_1)t) + (Am_2.\ Ac/2)\cos(2\pi(f - fm_2)t) + (Am_2.\ Ac/2)\cos(2\pi(f + fm_2)t) + (Am_n.\ Ac/2)\cos(2\pi(f - fm_n)t) + (Am_n.\ Ac/2)\cos(2\pi(f + fm_n)t) + Ac\cos(2\pi fc\ t)$$

Let:

```
Am1=3 # amplitude of message signal

fm1=1000 # fequency of carrier signal
Am2=2 # amplitude of message signal
fm2=2000 # fequency of carrier signal
Am3=1 # amplitude of message signal
fm3=3000 # fequency of carrier signal
Ac=1 # amplitude of carrier signal
fc=10000 # fequency of carrier signal
```

The signals were plotted in time and frequency domain as shown in fig belo

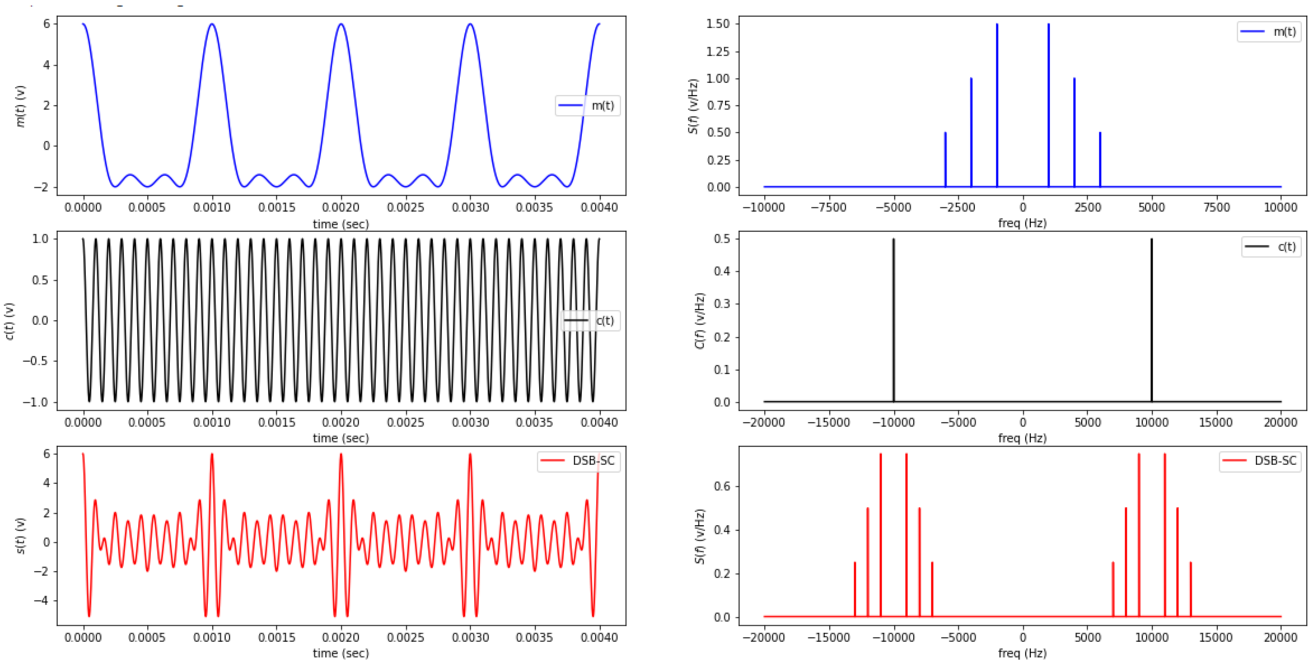

Figure 6: DSB-SC modulation of a message signal with multiple harmonics

- **<u>Note</u>**: We notice 3 signal in the above figure, m(t) -massage- that contains 3 massage signals (3 cos) ,c(t) - carrier - each with a different shape, amplitude and frequency. S(t) –DSB modulation signal- signal That depend on m(t) and c(t).

2.2.2 <u>Exercise:</u>

2.2.2.1 $fm_1=500$, $fm_2=1000$, $fm_3=1500$:

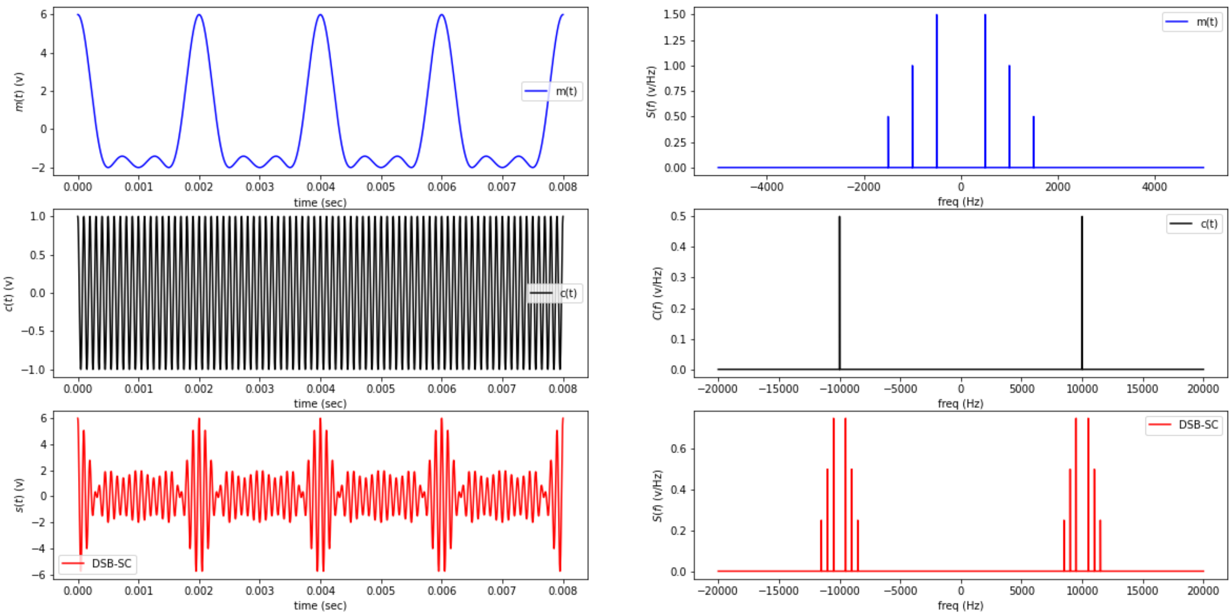

Figure 7: DSB-SC modulation of a message signal with multiple harmonics(fm1=500,fm2=1000,fm3=1500)

- **<u>Note</u>**: when fm was change the waves for massage change . also the carrier envelop and DSB signal waves affected. in addition to the DSB signal frequency between the carrier frequency changed by :
  (fc-fm , fc+fm) and (-fc-fm , -fc+fm)
  But the carrier frequency and the amplitude of frequency for DSB signal doesn’t affected.

2.2.2.2 fc=8000 Hz :

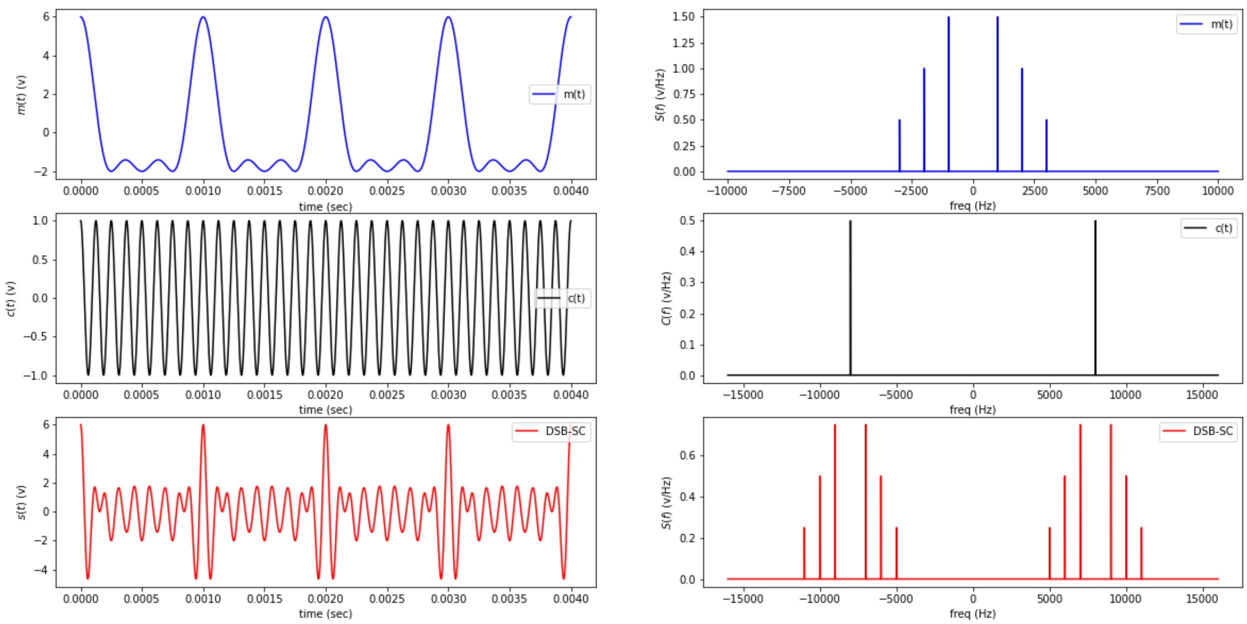

Figure 8: DSB-SC modulation of a message signal with multiple harmonics fc=8000

- **Note:** when fc was decreased/increase the envelop and frequency of massage signal were not affected . but waves for carrier envelop and DSB signal waves expand and move away from each other if decreased or close together if increase . And the DSB signal frequency changed by: (fc-fm , fc , fc+fm) , (-fc-fm , -fc , -fc+fm).

  But the amplitude of frequency for DSB signal doesn't affected.

2.2.2.3 $Am_1=2$, $Am_2=4$, $Am_3=0$:

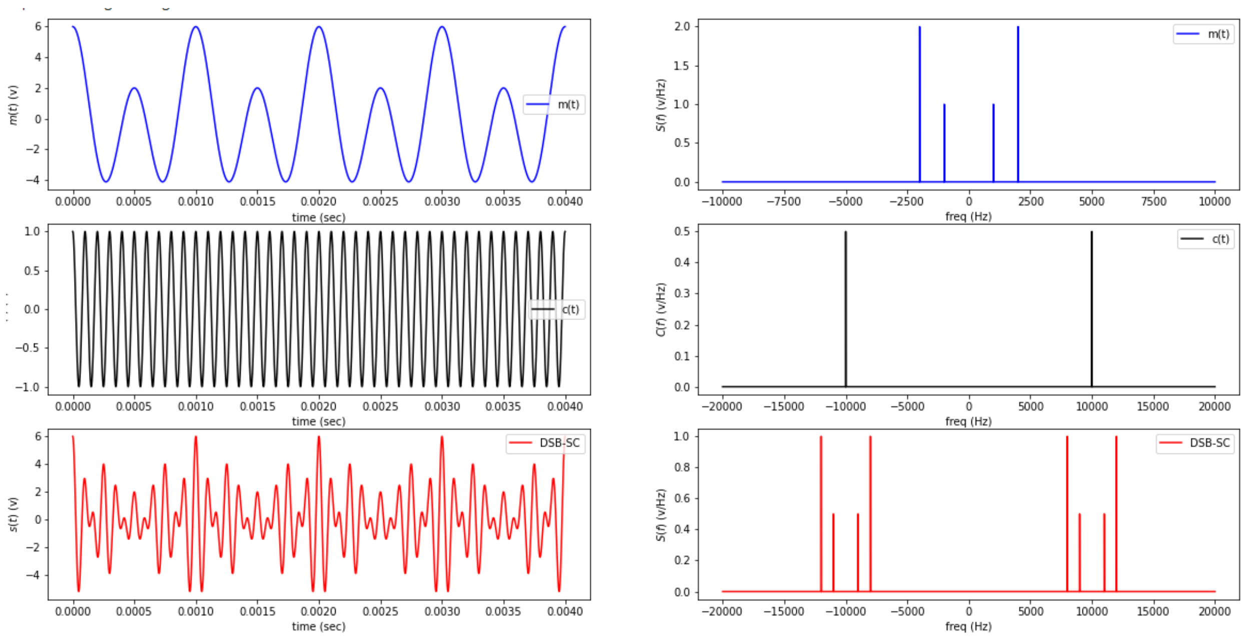

Figure 9: DSB-SC modulation of a message signal with multiple harmonics(Am1=2,Am2=4,Am3=0)

- **<u>Note</u>:** At the beginning, we notice when we put ($Am_3=0$) this massage (m_3) has disappeared. Also, when Am increased/decreased the peak of the massage increases /decreases and the amplitude of DSB signals envelope increases/decreases by (Ac.Am). in addition to, massage amplitude frequency value changes by ($A_m/2$) also for the upper and lower parts in DSB frequency change by ((A_m.Ac/2) , but the site that followed is not affected. While for carrier envelop and frequency were not affected.

2.2.2.4 Ac=2 :

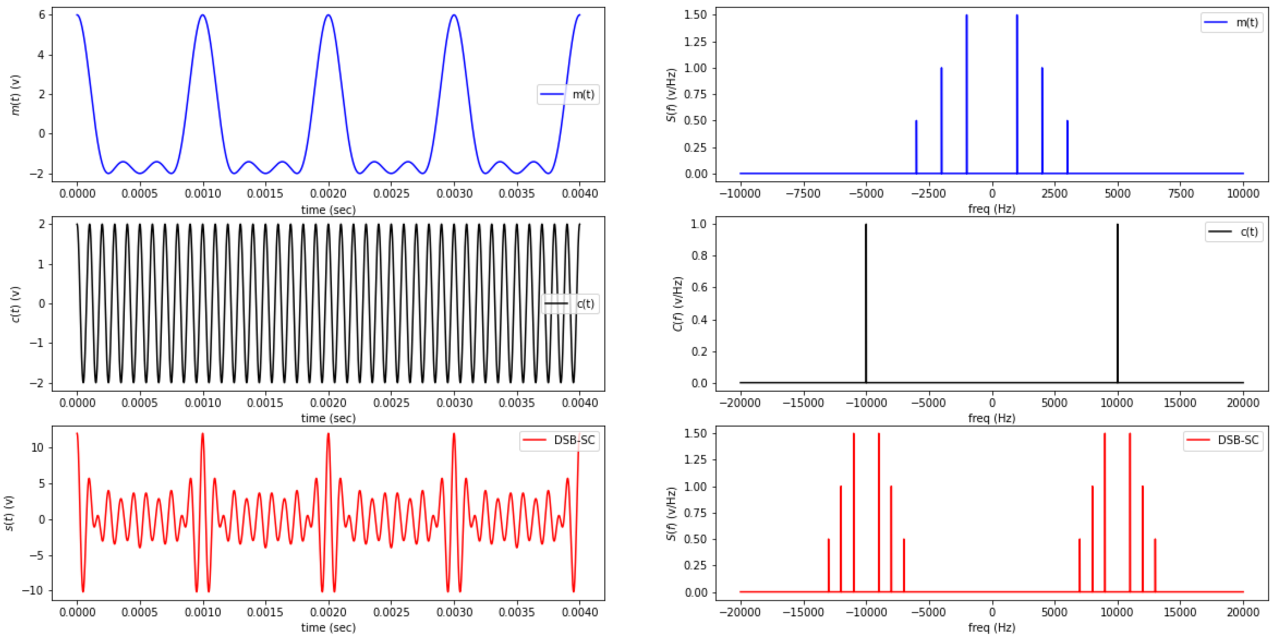

Figure 10: DSB-SC modulation of a message signal with multiple harmonics Ac=2

- **Note:** when Ac increase/decrees the peak of the carrier increases/decreases and DSB signals envelope increases/decreases by (Ac.Am) . in addition to, carrier amplitude frequency value changes by (A_c/2) , also for the upper and lower parts in DSB frequency change by ((A_m.Ac/2) , but the site that followed is not affected. While for massage envelope and frequency doesn't change.

2.3 Demodulation of DSB-SC modulation using coherent demodulation:

2.3.1 Equation and result without any change:

$$r(t)=c(t).s(t)=c(t).m(t).c(t)=(Ac)^2.m(t).\cos^2(2\pi f_c t)$$

Where:

r(t): The demodulating signal.

m(t): message signal.

A_c: The amplitude of the carrier signal.
f_c: The frequency of the carrier signal.

Then, use a LPF is used to recover the message signal.

Let:

```
Am1=3 # amplitude of message signal
fm1=1000 # frequency of message signal
Am2=2 # amplitude of message signal
fm2=2000 # frequency of message signal
Am3=1 # amplitude of message signal
fm3=3000 # frequency of message signal
Ac=1 # amplitude of carrier signal
fc=10000 # frequency of carrier signal
f3db = 6000  # Cut-off frequency of the filter
forder=5 # order of the filter
```

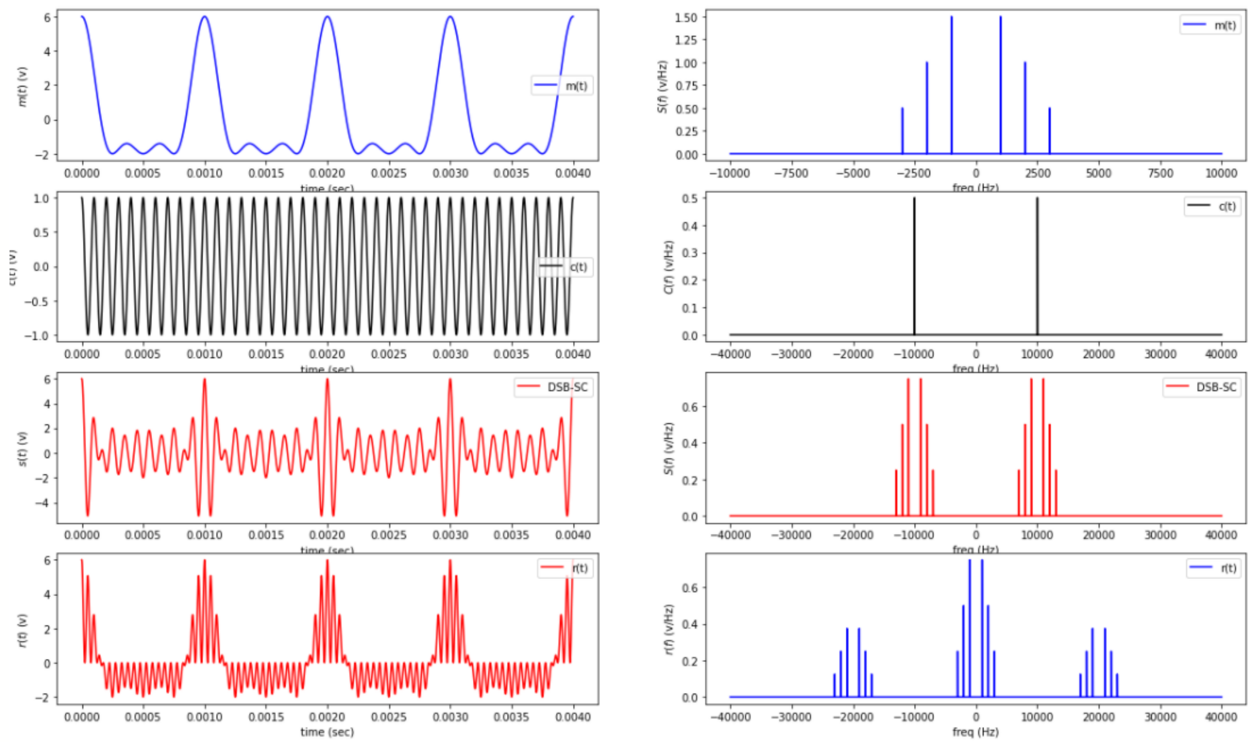

Figure 11: m(t), c(t), s(t) and r(t) in time and frequency domain

- **<u>Note</u>**: As we can see in the figure above, one of the steps in the action of (demodulation of DSB-SC) is multiplying S(t) by C(t). As a result, the S(t) shifted with an amount of fc, as it is clear in the fourth plot in above figure. In addition to, we can notice that the signal in the middle is represented the massage signal. Then, use a LPF to recover the message signal.

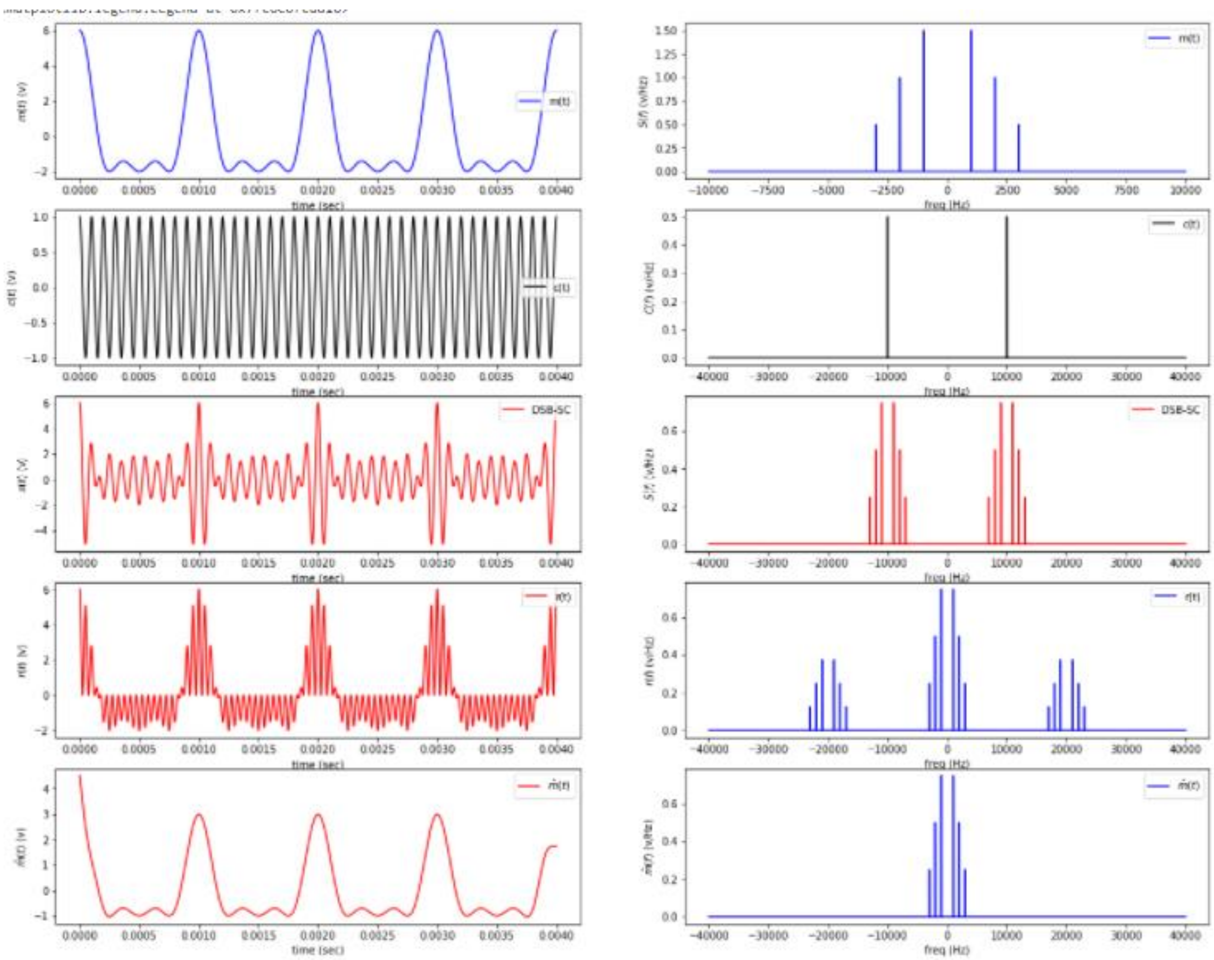

Figure 12: m(t), c(t), s(t) and r(t) in time and frequency domain with recovered signal

- **<u>Note</u>**: a Low pass filter was used to recover the modulated signal m^(t) and remove the high frequency components at 2fc and −2fc with Butterworth Low Pass filter with Bandwidth equal to f3dB. filter was applied with f3dB=BW and observe the output were BW is the bandwidth of m(t).

2.3.2 <u>Exercise:</u>

2.3.2.1 <u>fc=5000 Hz :</u>

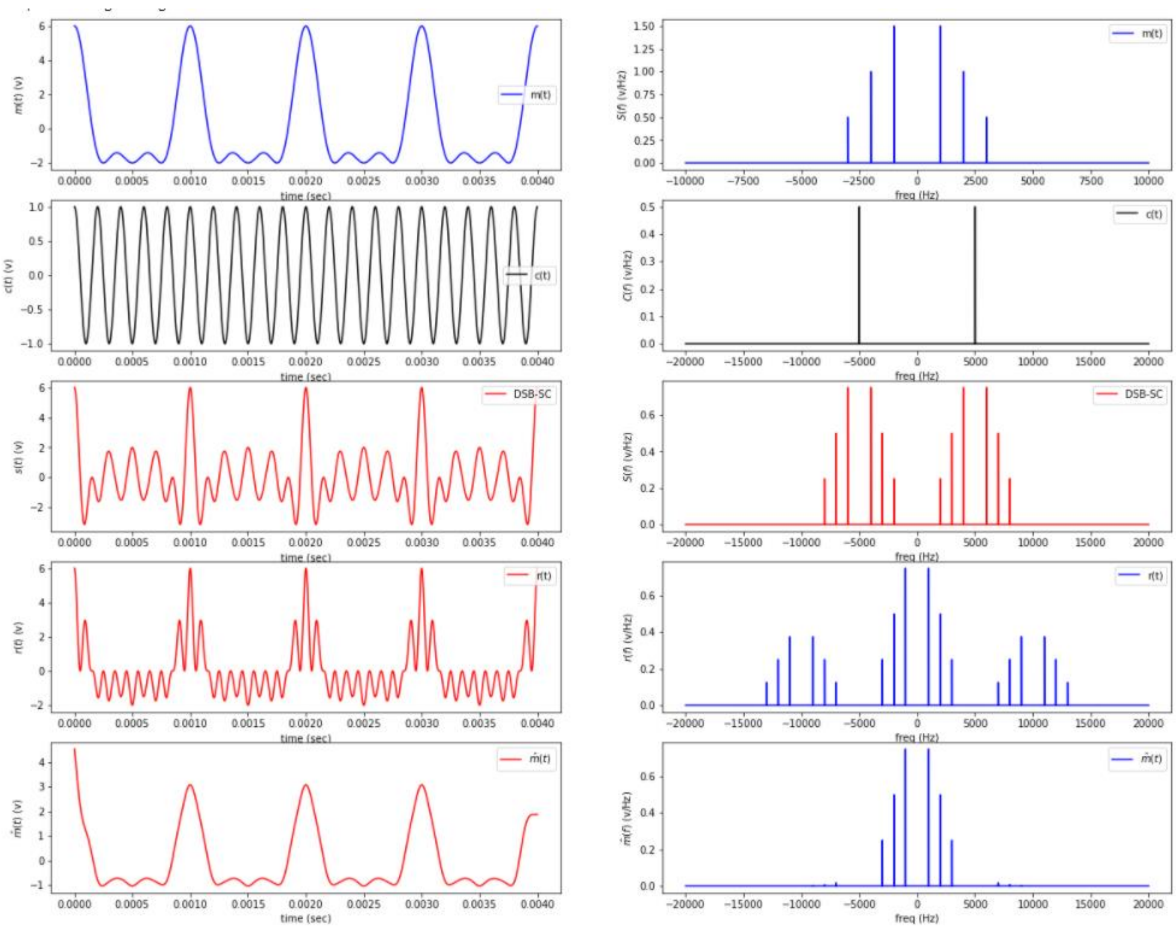

Figure 13: m(t), c(t), s(t) in time and frequency domain with fc=5000hz

- **<u>Note</u>**: when fc was decreased/increase the envelop and frequency of massage signal were not affected . but waves for carrier , DSB signal waves, demodulation signal and recover massage envelops affected and changed. Whereas in frequency domain we made shifted and this shifted depends on value of carrier frequency because of that There is a change when the value of fc changed. But the amplitude of frequency for all of them don't affected.

2.3.2.2 fm1=1500 Hz , fm2=2500 Hz , fm3=3500 Hz :

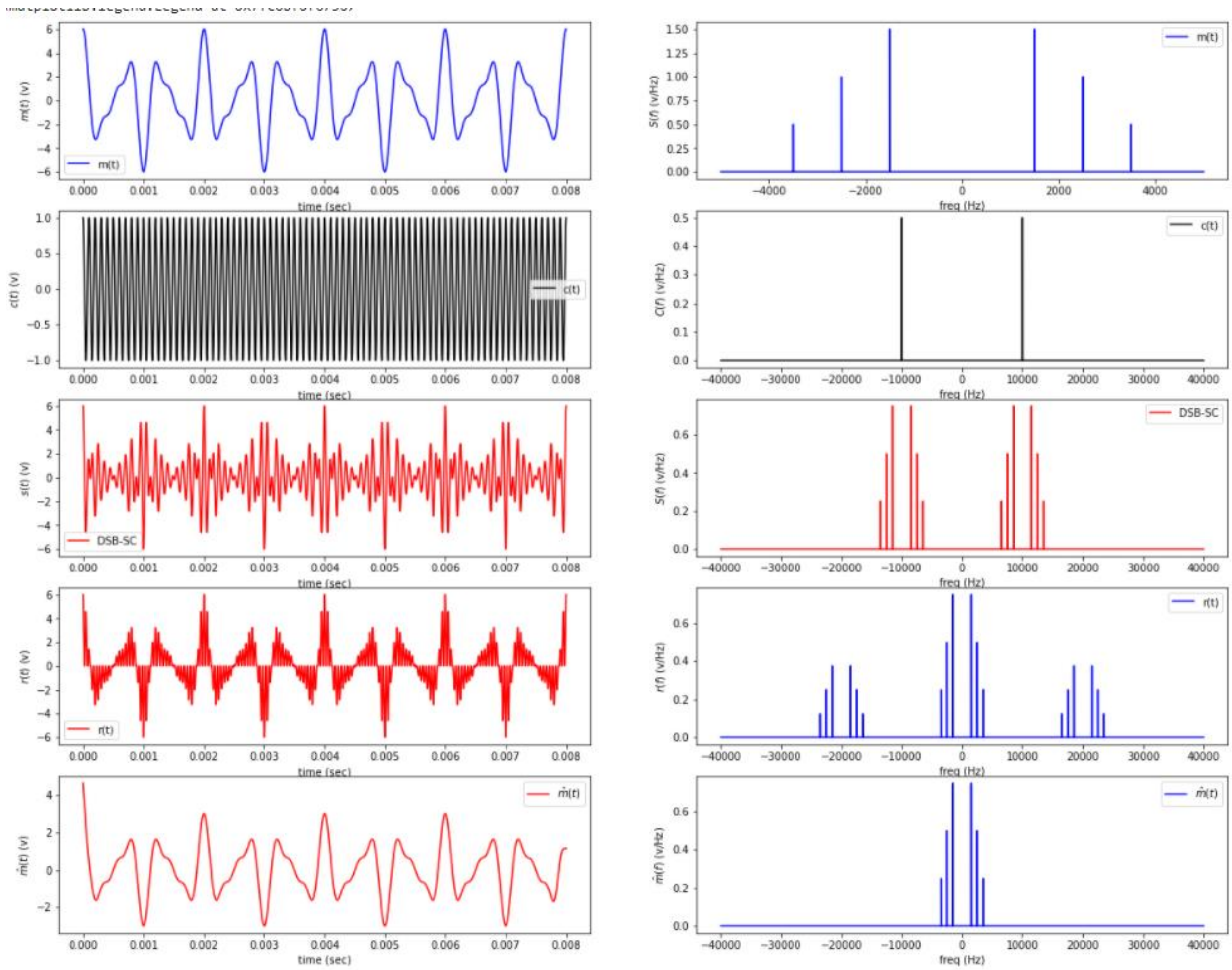

Figure 14:m(t),c(t), s(t) in time and frequency domain with (fm1=1500hz, fm2 =2500hz, fm3 = 3500hz)

- **Note**: when fm was decreased/increase the envelop and frequency of carrier signal was not affected . but waves for massages , DSB signal waves, demodulation signal and recover massage envelops affected and changed in time doman and frequency doman, This is because of the change in fm . But the amplitude of frequency for all of them don’t affected.

2.3.2.3 f3db :

2.3.2.3.1 f3db = 5000 :

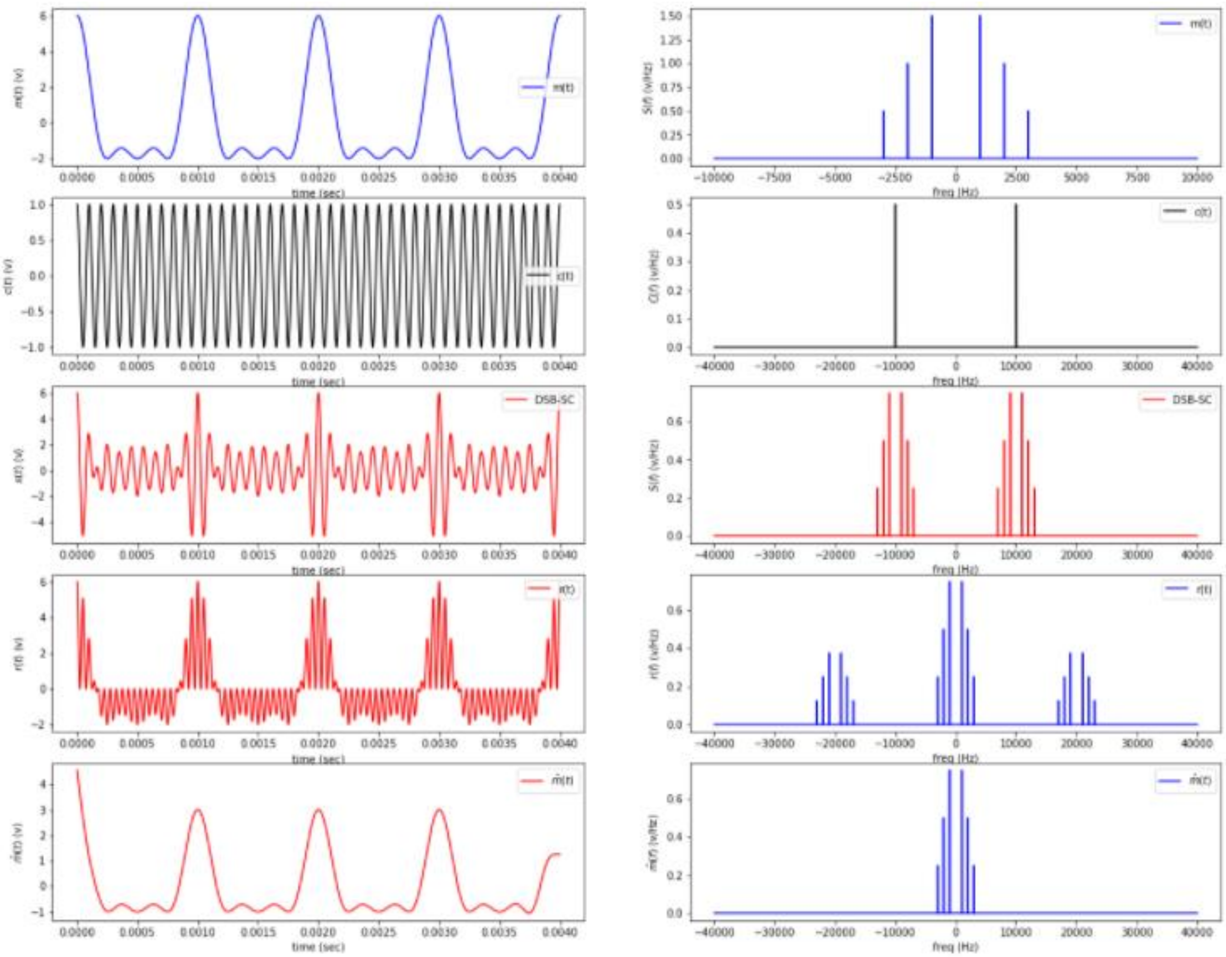

Figure 15: m(t), c(t), s(t) in time and frequency domain with f3dB =5000

- **Note**: In this case, when cut-off frequency was greater than frequency of the massage signal , we noticed that the Low pass filter passed all the massage and no attenuation occurred on it, and we were able to recover it.

2.3.2.3.2 f3db = 3000 :

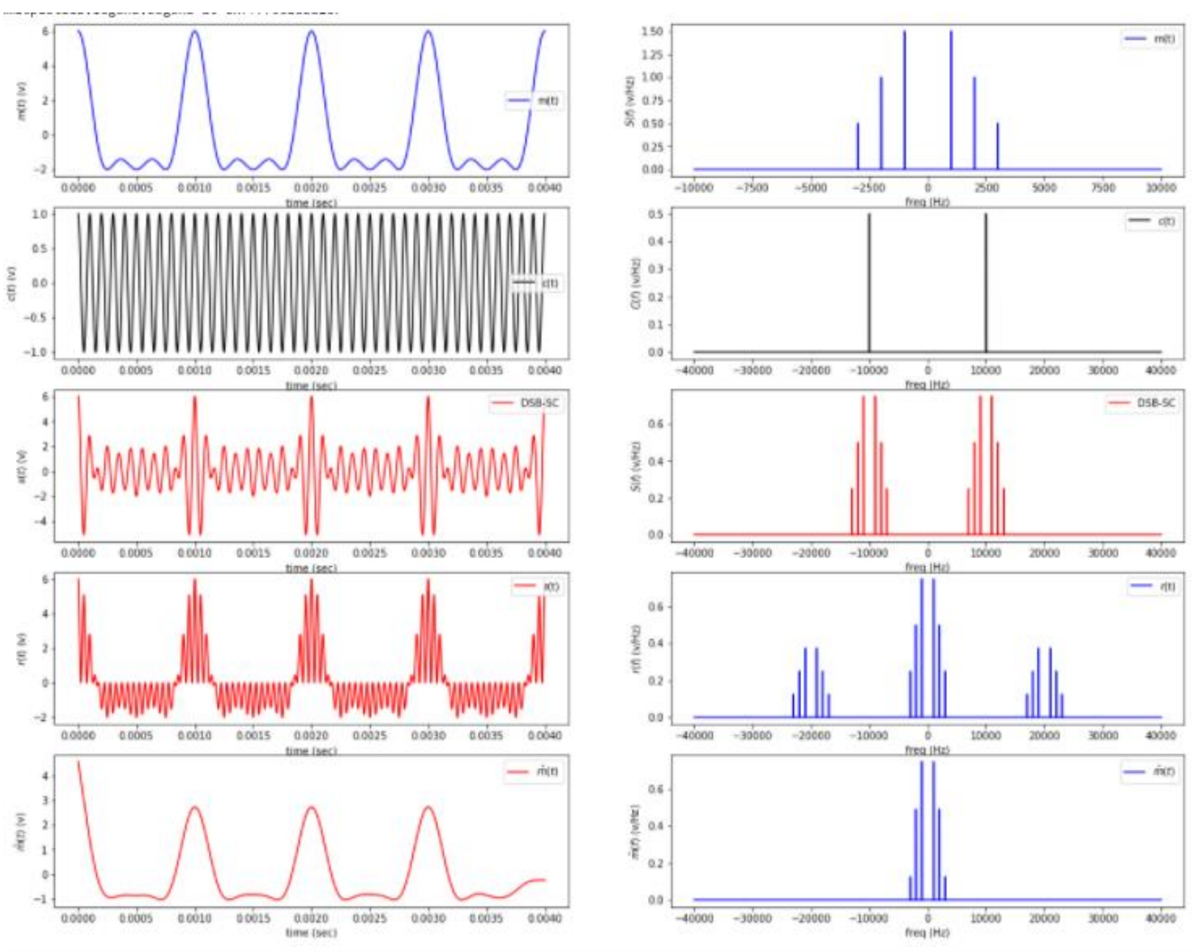

Figure 16m(t), c(t), s(t) in time and frequency domain with f3dB =3000

- **Note**: In this case, when cut-off frequency was equal high frequency of the massage signal , we noticed that the Low pass filter passed all the massage, but some of them happened to him attenuation especially those that have a higher frequency. Because it isn't from the range of filter.

2.3.2.4 Order of the LPF = 6

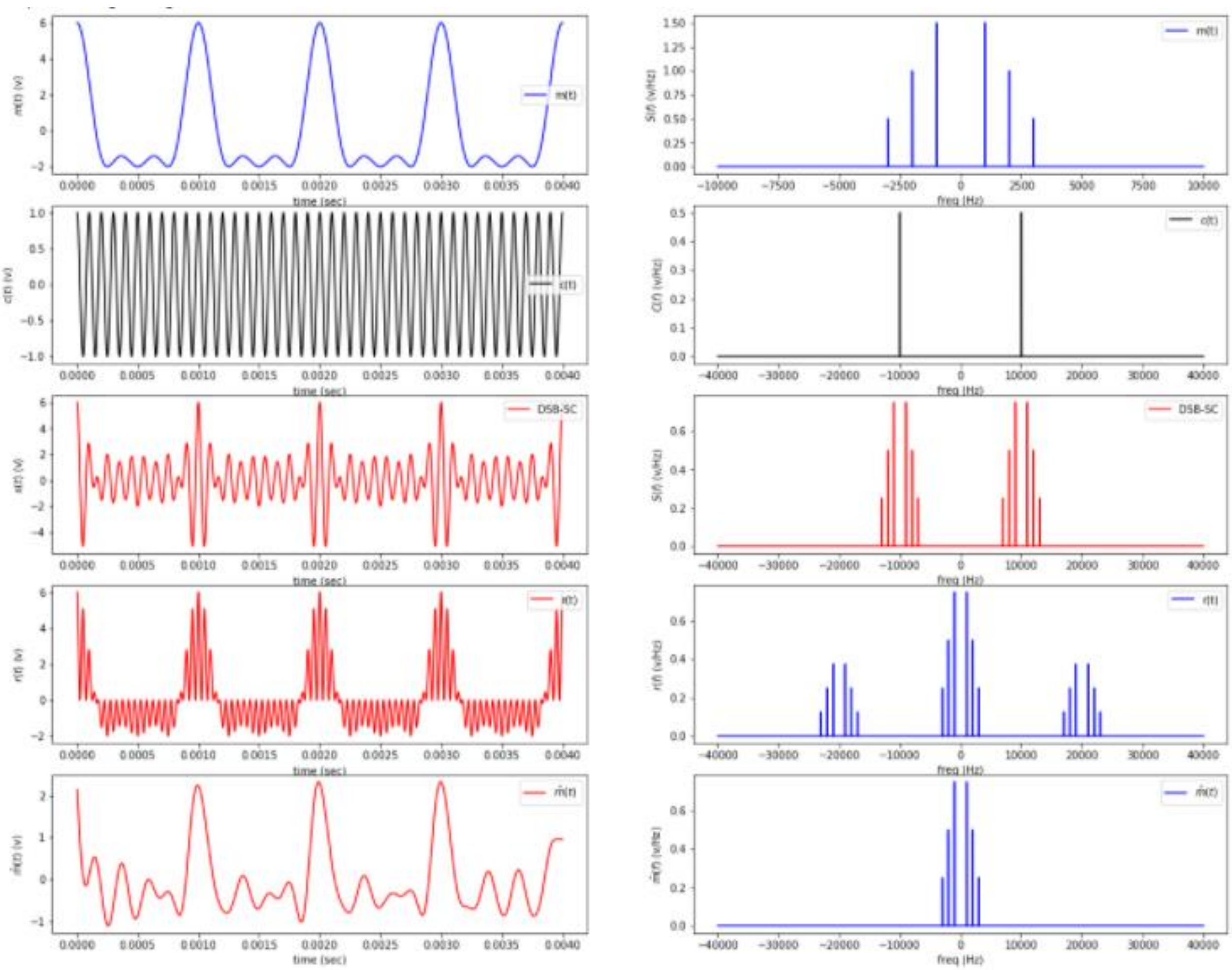

Figure 17:m(t), c(t), s(t) in time and frequency domain with Order of the LPF = 6

- **Note:** when increased the order of the LPF The sharpness of transition band increases and the attenuation during transition band decreases, in addition to the range between pass band and stop band is simple.

2.4 DSB-SC modulation/demodulation: effect of carrier non coherence in phase on demodulated signal:

2.4.1 Equation and result without any change:

Let the following:

$c(t)$ = Ac Cos (2πfct) $c`(t)$ = $Ac`$ Cos (2πfct + θ)

Where:

C(t): carrier signal.

C'(t): carrier with shifted phase.

A_c: The amplitude of the carrier signal.

A_c': The amplitude of the carrier signal who has shifted phase.
f_c: The frequency of the carrier signal.

V(t)= c(t) . $c`(t)$

The output of the low pass filter will be:

$Y(t) = (A_c . A_c' /2)\ m(t). \cos(\theta)$

Let:

```
Am1=3 # amplitude of message signal
fm1=1000 # frequency of message signal
Am2=2 # amplitude of message signal
fm2=2000 # frequency of message signal
Am3=1 # amplitude of message signal
fm3=3000 # frequency of message signal
Ac=1 # amplitude of carrier signal
fc=10000 # fequency of carrier signal
f3db = 6000  # Cut-off frequency of the filter
forder=5 # order of the filter
Phi=80 #carrier noncoherence in phase
```

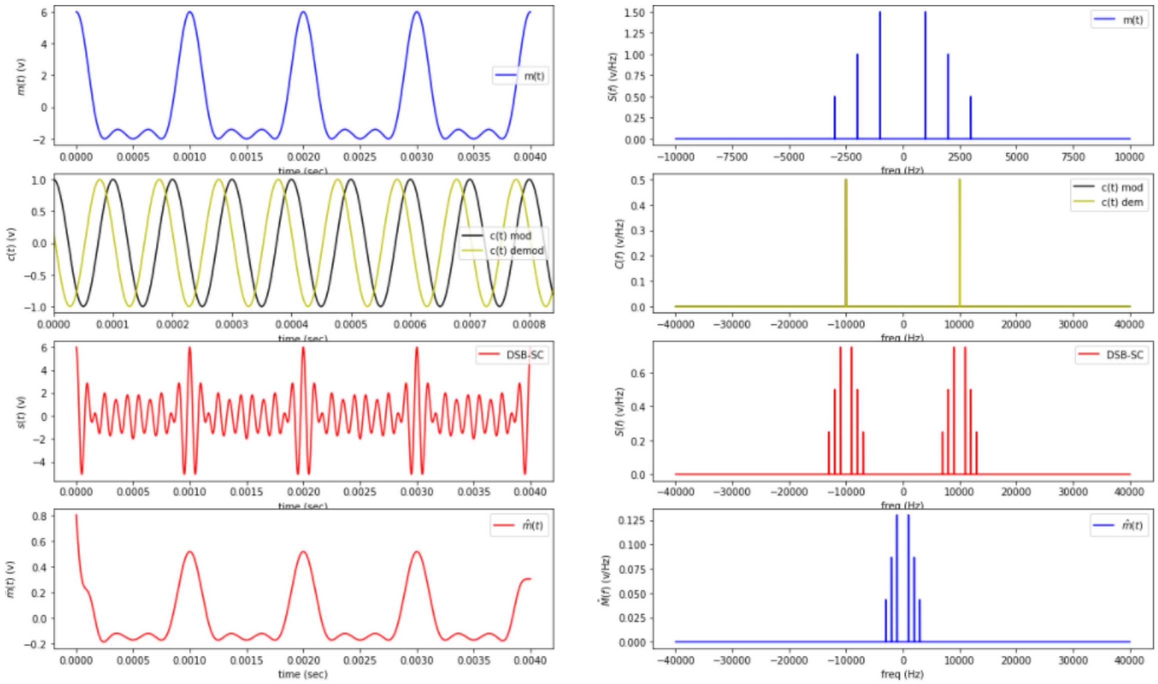

Figure 18: DSB-SC demodulation with carrier noncoherence in phase

- **<u>Note:</u>** in this case when (θ=80) we notice that m^(t) signal in time domain happened to it some attenuation as the amplitude changed from 6 to 0.4. But until now, I can have recovered the massage by using amplifier. In addition to, in the second figure of the figure above, there is a 2 carriers in time domain The first one to modulator and its color black but the second one to demodulator and its color yellow. While in frequency domain the 2 deltas have the same frequency located on top of each other.

2.4.2 **Exercise:**

2.4.2.1 **$\theta=85^0$:**

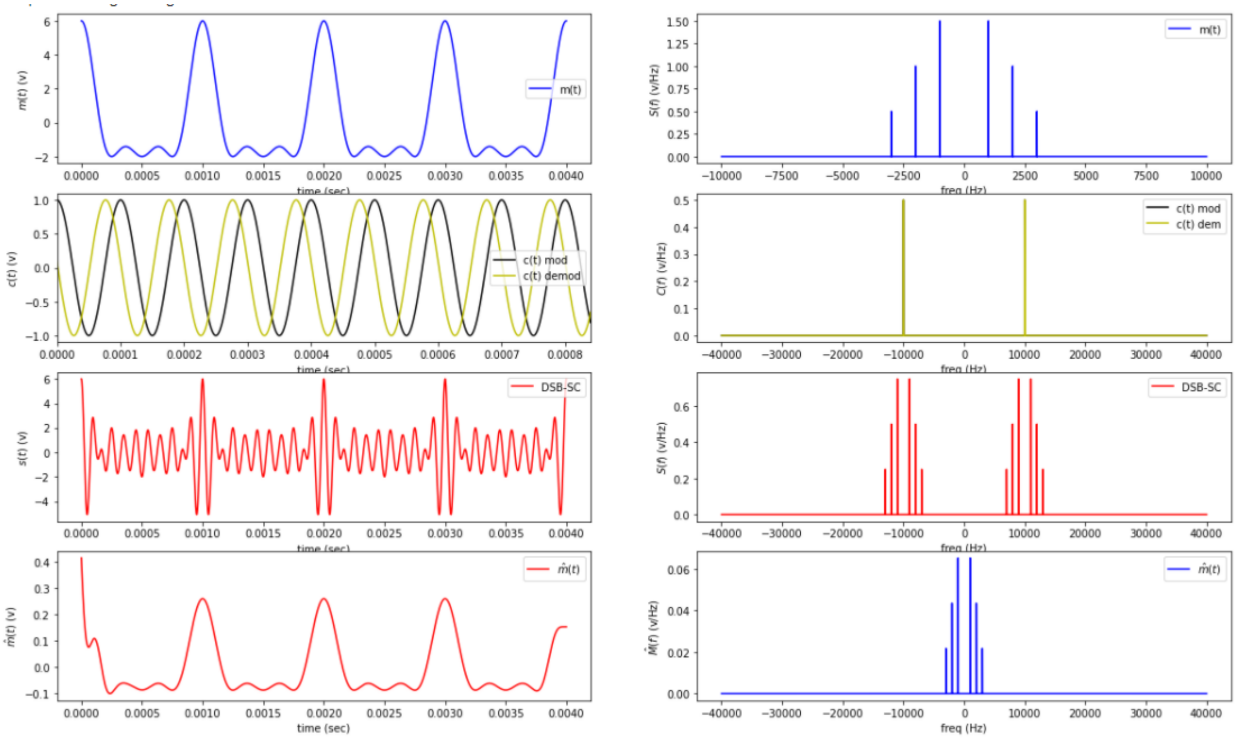

Figure 19: DSB-SC demodulation with carrier non coherence 85 -degree phase

- **Note:** When we increase the value of θ, we notice that there has been an attenuation on $m^{\wedge}$(t)signal significantly, but until now we can have recovered the massage by using the amplifier.

2.4.2.2 θ=90^0 :

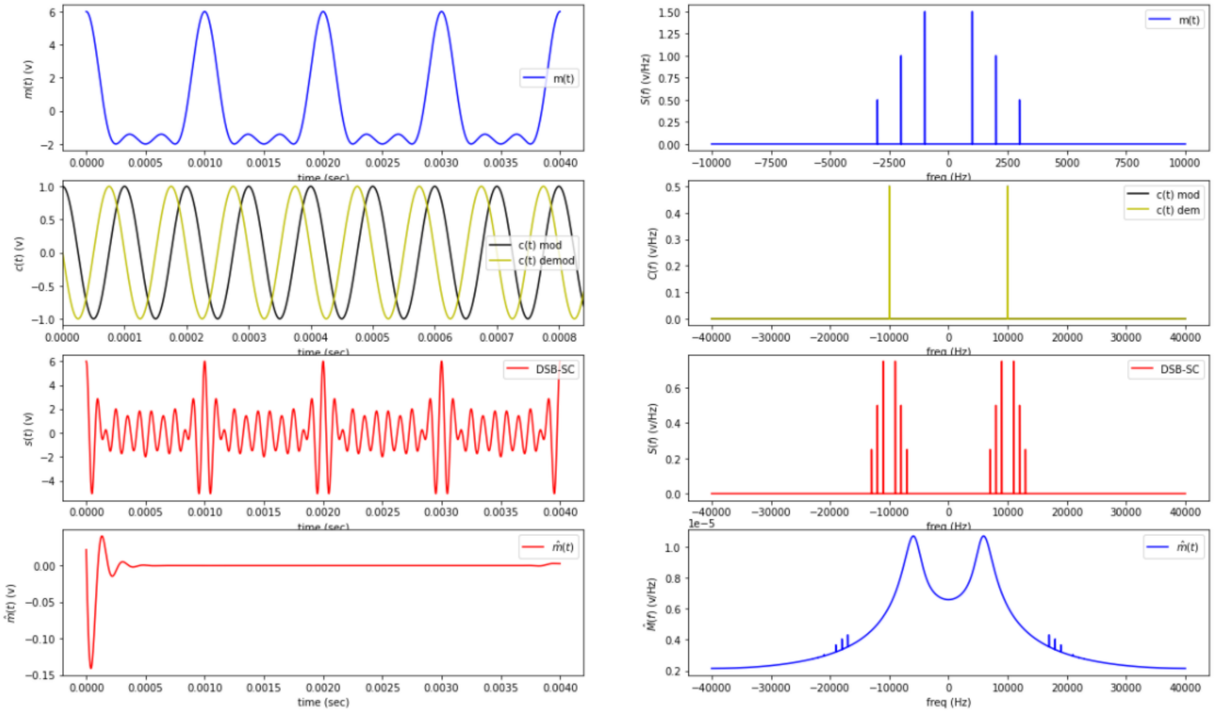

Figure 20: DSB-SC demodulation with carrier non coherence 90-degree phase

- **Note:** in this case when we increase the value of θ (θ=90), we notice that the m^(t) signal Significantly weakened, so in this case we cannot recovered the massage.

2.5 DSB-SC modulation/demodulation: effect of carrier non coherence in frequency on demodulated signal:

2.5.1 Equation and result without any change:

Let the following:

$c(t)$ = Ac Cos (2πfct) $c`(t)$ = $Ac`$ Cos (2πfct + ∆f)

Where:

C(t): carrier signal.

C'(t): carrier with shifted frequency.

A_c: The amplitude of the carrier signal.

A_c': The amplitude of the carrier signal who has shifted frequency.
f_c: The frequency of the carrier signal.
∆f: Difference between fc and fc'

V(t)= c(t) . $c`(t)$

The output of the low pass filter will be:

Y(t) = ($A_{c.}$ A_c' /2) m(t). Cos (2π.∆f.t)

Let:

```
Am1=3 # amplitude of message signal
fm1=1000 # fequency of carrier signal
Am2=2 # amplitude of message signal
fm2=2000 # fequency of carrier signal
Am3=1 # amplitude of message signal
fm3=3000 # fequency of carrier signal
Ac=1 # amplitude of carrier signal
fc=10000 # fequency of carrier signal
f3db = 6000  # Cut-off frequency of the filter
forder=5 # order of the filter
df=500 #carrier noncoherence in frequency
```

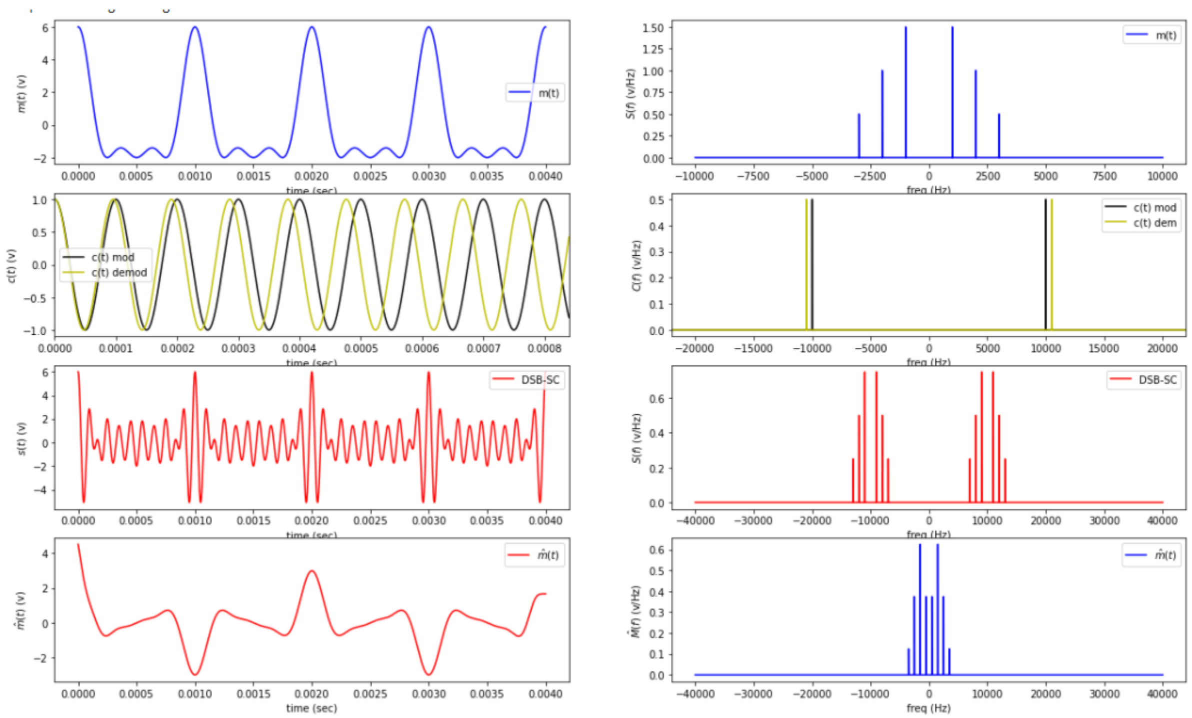

Figure 21: DSB-SC demodulation with (df) of 500 Hz

- **<u>Note</u>**: in this case we notice that $m^{\wedge}(t)$ signal in time domain happened to it distortion. So, it became not like the original massage and in this case we cannot recovered the massage signal. In addition to, in frequency domain there is no similarity between it and the original massage. Also, in the second figure of the figure above, there is a 2 carriers in time domain The first one to modulator and its color black but the second one to demodulator and its color yellow and the two are different from each other. While in frequency domain Each carrier has its own frequency which differs from the other.

2.5.2 <u>Exercise:</u>

2.5.2.1 fc = 5000 Hz :

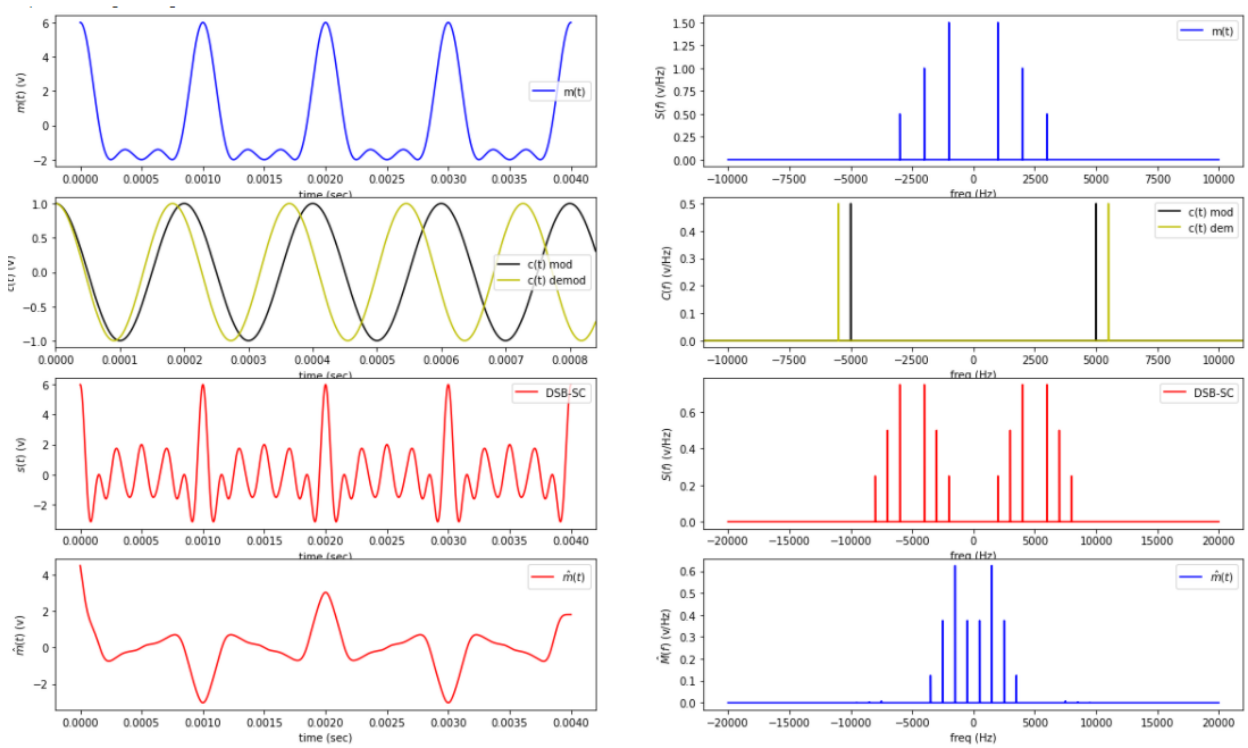

Figure 22: DSB-SC demodulation with fc= 5000 Hz

- **<u>Note:</u>** In this case, we got results similar to the previous case, but with the small differences in time and frequency domain of carrier part in the figure above (like: position of carrier in frequency domain and distance between the two carrier envelop in time domain). So, we notice that changing in fc value (increases/decreases) It does not affect my ability to eliminate distortion and restore the massage signal, but it affects the value of the shift that the massage gets.

3. Conclution:

In conclusion, we were able to understand the Working mechanism SSB-SC in modulation case and demodulation case. Also, we were able to understand the effect of changing the parameters on the recovered signal. We were able to understand the purpose of using different modulators and demodulators based on the type of the signal. Finally, the experiment ran smoothly using the Colab and our results were logical and convincing.