BERZIET UNIVERSITY

FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ENEE 4113

communication Laboratory.

Experiment 3

SSB Modulation and Demodulation

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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:

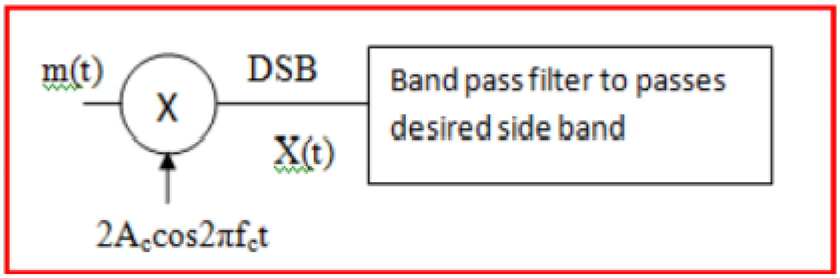
Table of figure:

2. Procedure:

2.1 SSB-SC modulation in the time and frequency domains - Frequency Discrimination Method:

2.1.1 Equation and result without any change:

In SSB-SC, the formula of the modulated signal like DSB-SC but it is passed on Band Pass Filter :



Where:

X(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 :

```
Am1=3 # amplitude of message signal
fm1=1000 # fequency of carrier signal
Ac=1 # amplitude of carrier signal
fc=10000 # fequency of carrier signal
forder=1 # order of the filter
```

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

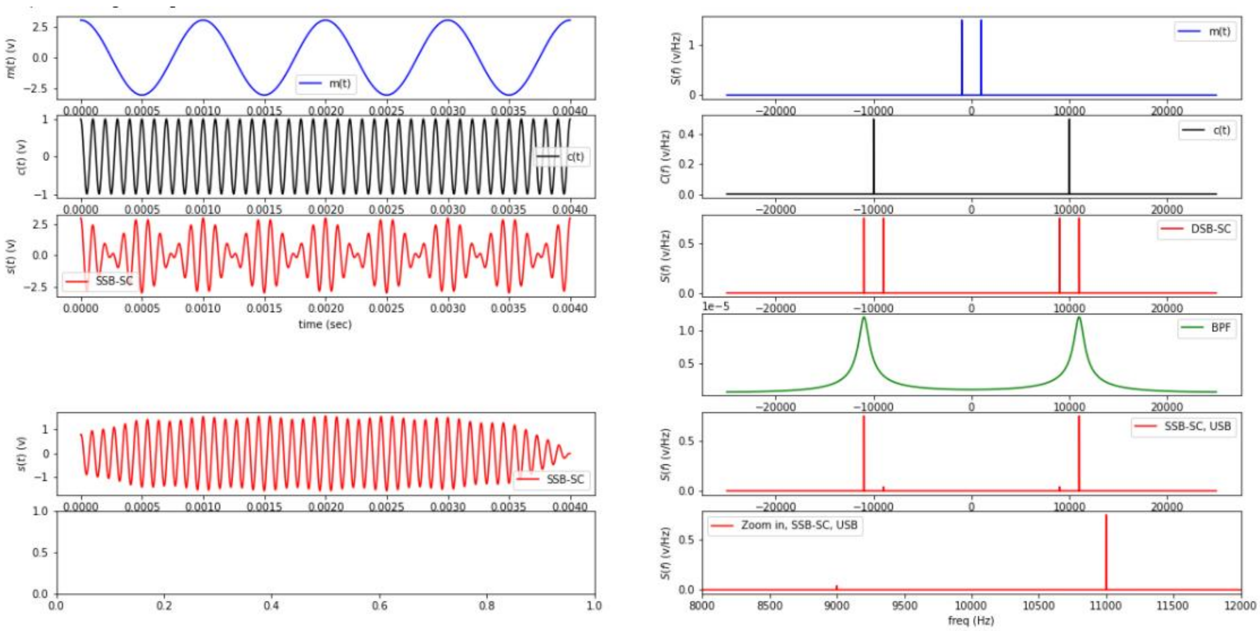


Figure 1: m(t), c(t), s(t) in time and frequency domain

- **<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- That will be passed on Band Pass Filter to modulate SSB-SC and keep one of two sidebands (upper side band) in this case.

2.1.2 **Exercise:**

2.1.2.1 **fm = 500 Hz :**

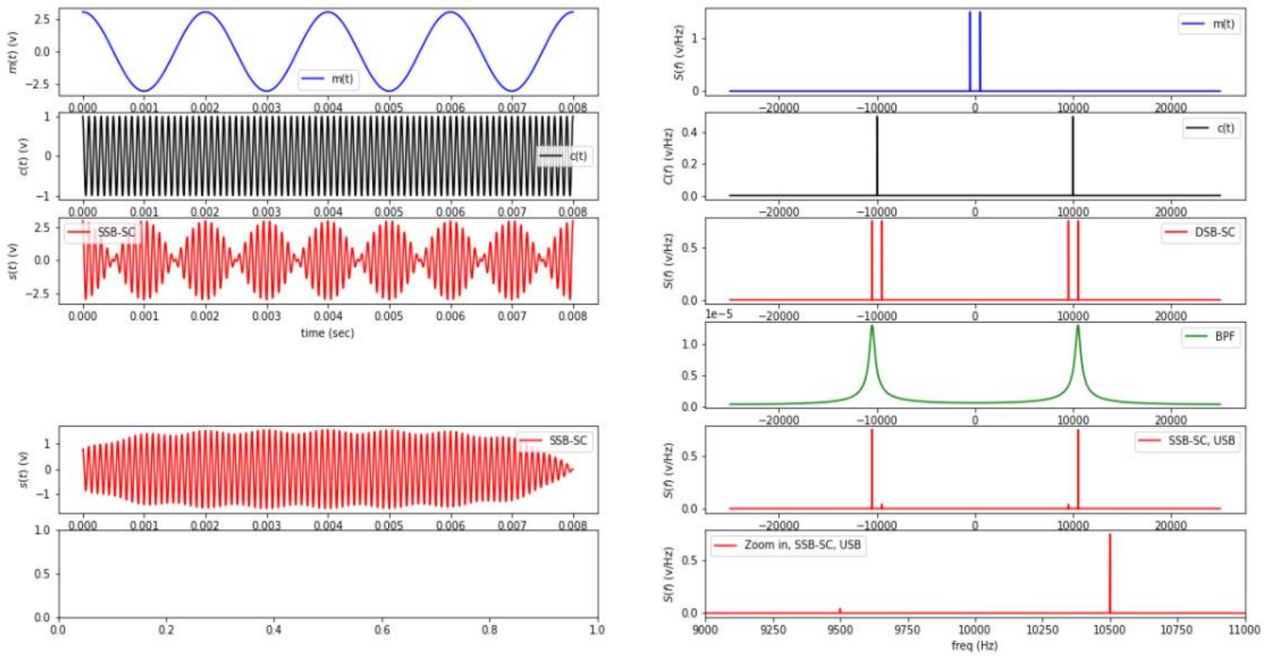


Figure 2:m(t), c(t), s(t) in time and frequency domain with fm = 500

- **Note:** When fm was decreased/increased:

1- The envelop, frequency and BW for massage signal were affected.

2- The envelop and frequency for carrier signal were not affected.

3- The envelop for DSB signal waves envelop close together if deceased or move away from each other if increases. in addition to, their frequency changed by:
(fc-fm , fc+fm) =>(10000-500, 10000+500)
(-fc-fm , -fc+fm) =>(-10000-500,-10000+500)
But their amplitude was not affected.

4- The change in fm that affected on upper/lower cut off frequency for filter
lowcut_usb = fc+(fm/2)   highcut_usb = fc+(3fm/2)
so this affects the shape of the filter.

5- As a result of s(t) for DSB-SC change so s(t) for SSB-SC will change, Because the SSB-SC signal is the same of DSB-SC signal, but instead of having a two side band there is one side band -(upper side band or lower side band)- because it passed on filter.

6- As for the small signal that found in 9500 Hz that is because the filter we are using is not ideal so this signal was allowed to pass.

2.1.2.2 **<u>fc=5000 Hz</u> :**

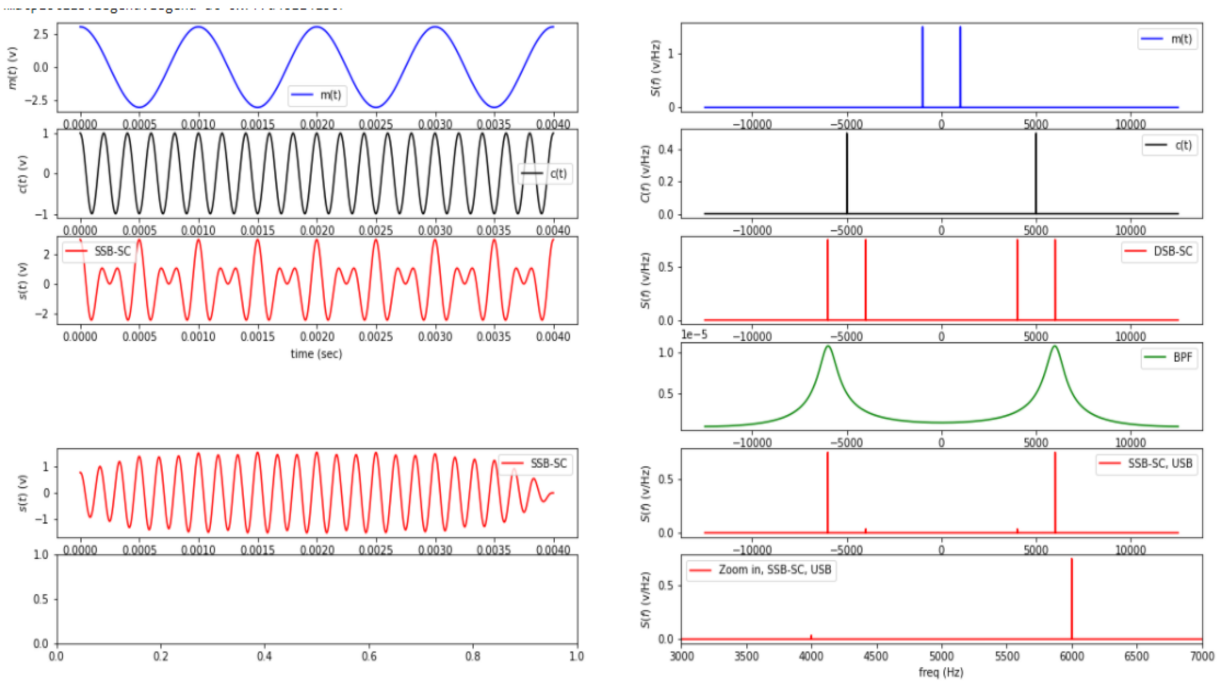


Figure 3: m(t), c(t), s(t) in time and frequency domain with fc = 5000

- **<u>Note</u>:** When fc was decreased/increased:

  1- The envelop and frequency for massage signal were not affected.

  2- The envelop and frequency for carrier signal were affected.

  3- The envelop for DSB signal envelop wave 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.

  4- The upper and lower cut off frequency for filter change by:
  lowcut_usb = fc+(fm/2)   highcut_usb = fc+(3fm/2)
  so this affects the shape of the filter.

  5- As a result of s(t) for DSB-SC change so s(t) for SSB-SC will change, Because the SSB-SC signal is the same of DSB-SC signal, but instead of having a two side band there is one side band -(upper side band or lower side band)- because it passed on filter.

  6- As for the small signal that found in 4000 Hz that is because the filter we are using is not ideal so this signal was allowed to pass.

2.1.2.3 <u>Am = 1.5:</u>

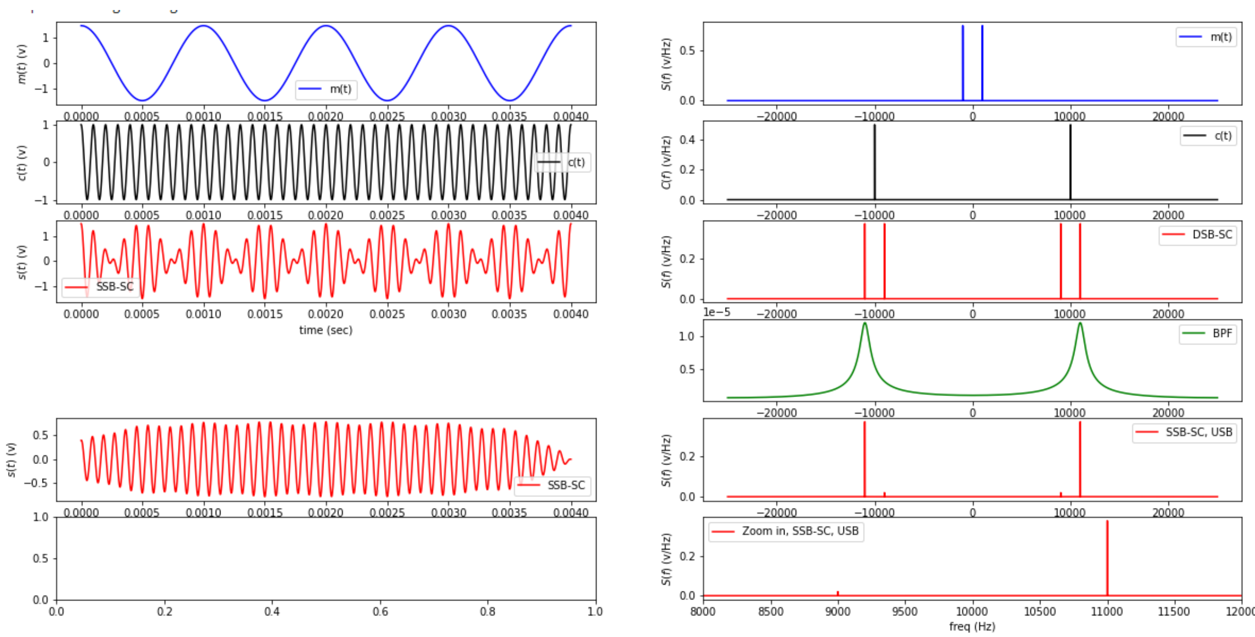


Figure 4:m(t), c(t), s(t) in time and frequency domain with Am = 1.5

- <u>**Note**</u>**:** When Am increased/decreased:
  1- The peak of the massage change (Am in time domain, (Am/2) in frequency domain) .
  2- The carrier envelop and frequency were not affected.
  3- The 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.

  4- The upper and lower cut off frequency for filter doesn't change so the shape of filter isn't affected.

  5- As a result of s(t) for DSB-SC change so s(t) for SSB signals will have the same change in time and frequency domain.

2.1.2.4 Ac = 2 :

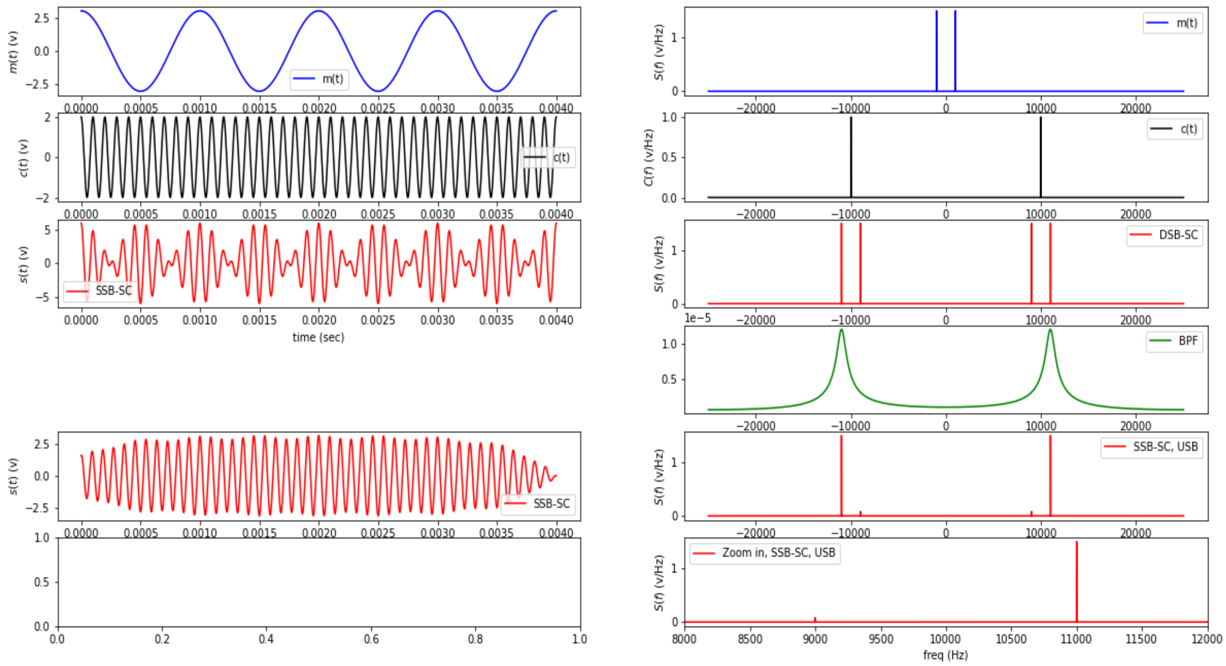


Figure 5: m(t), c(t), s(t) in time and frequency domain with Ac = 2

- **<u>Note</u>:** When Ac increased/decreased:
  1- The massage envelop and frequency were not affected
  2- The peak of the carrier change (Ac in time domain, (Ac/2) in frequency domain) .
  3- The 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.

  4- The upper and lower cut off frequency for filter doesn't change so the shape of filter isn't affected.

  5- As a result of s(t) for DSB-SC change so s(t) for SSB signals will have the same change in time and frequency domain.

2.1.2.5 forder=2:

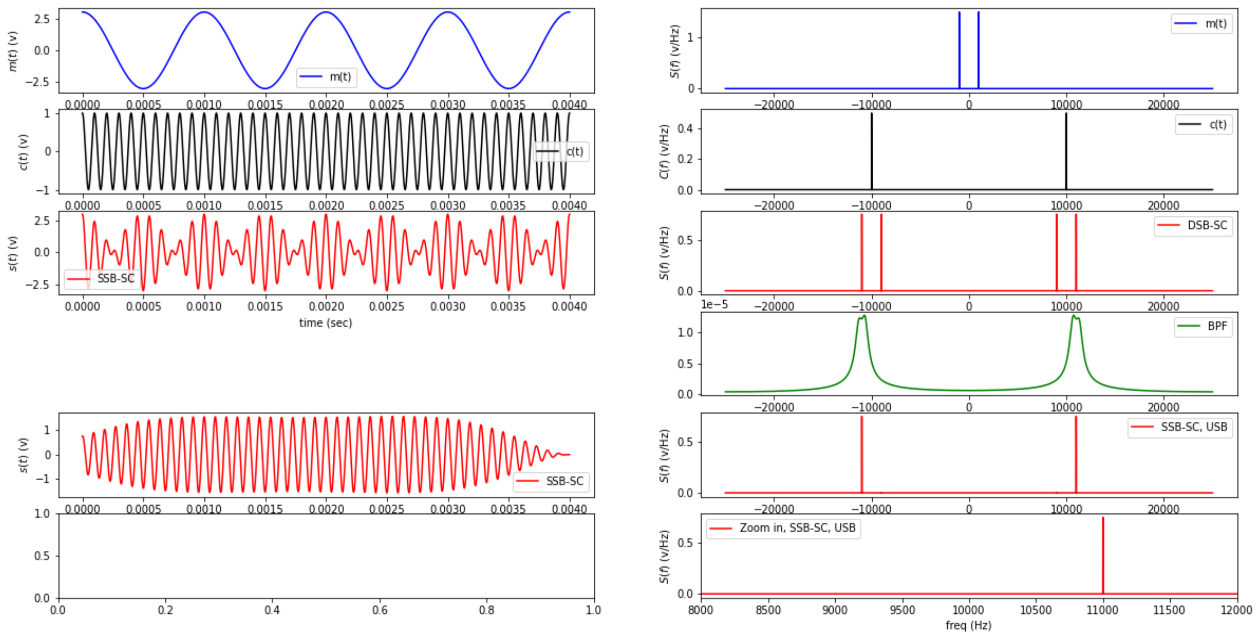
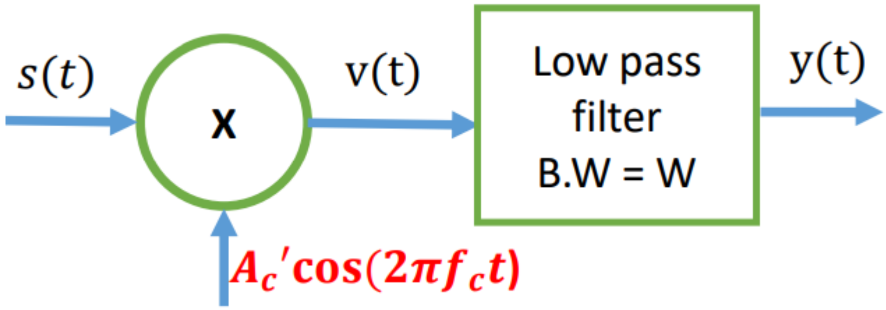


Figure 6:m(t), c(t), s(t) in time and frequency domain with forder=2

- **Note:** As we mentioned in the past, there is a small signal that has passed through the filter because the filter is not ideal so in order to get rid of this signal we have made a small change in order of the filter so in this way, we were able to get rid of this signal.

2.2 SSB-SC demodultion in the time and frequency domains - Frequency Discrimination Method:

2.2.1 Equation and result without any change:



where:

s(t): The modulated signal.

v(t): The demodulating signal.

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

$$y(t) = \frac{A_C A_C'}{2} m(t)$$

Let:

```
Am1=3 # amplitude of message signal

fm1=1000 # fequency of carrier signal
Ac=1 # amplitude of carrier signal
fc=10000 # fequency of carrier signal
forder=2 # order of the filter
```

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

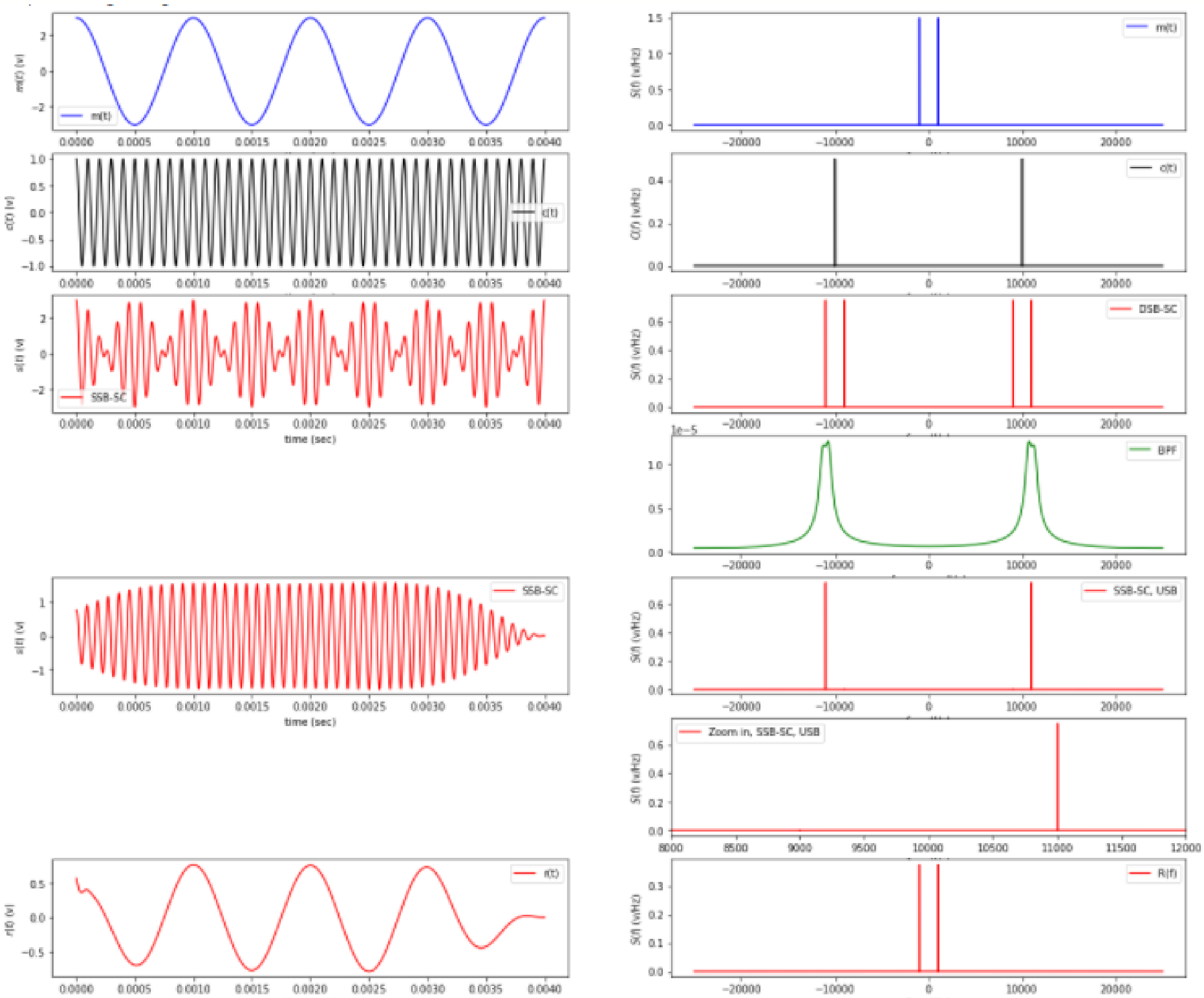


Figure 7: m(t), c(t), s(t) and r(t) in time and frequency domain

- **<u>Note</u>**: As we can see in the figure above, one of the steps in the action of (demodulation of SSB-SC) is multiplying S(t) for SSB-SC by C(t). As a result, the S(t) shifted with an amount of fc, then use a LPF to recover the message signal as it is clear in the seventh plot in above figure. as we also note in time domain, there are some distortion, that can be disposed of.

2.2.2 <u>Exercise:</u>

2.2.2.1 <u>fm=500 Hz :</u>

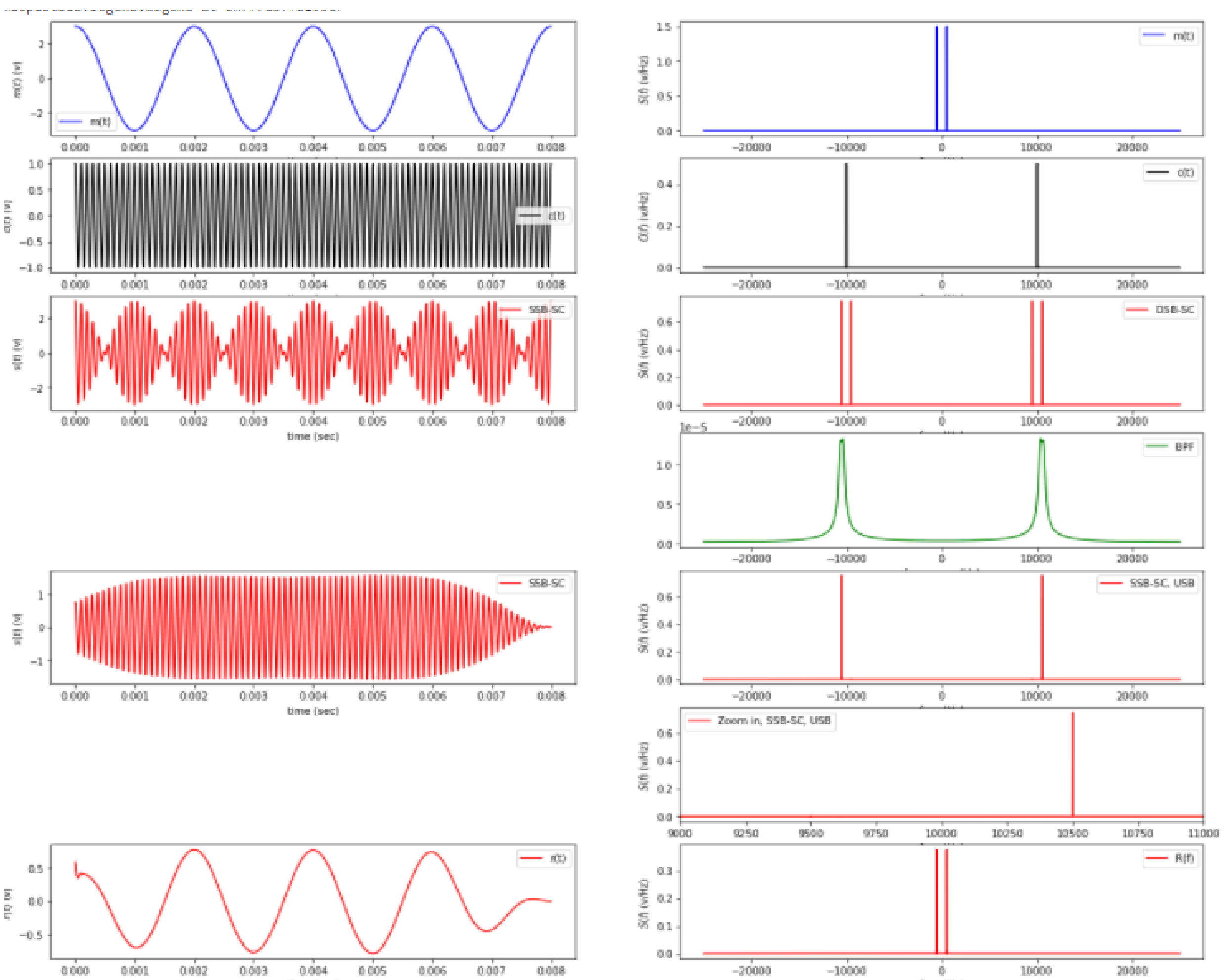


Figure 8:m(t), c(t), s(t) and r(t) in time and frequency domain with fm=500 Hz

- **<u>Note</u>**: When fm was decreased/increased:

  1- The envelop, frequency and BW for massage signal were affected.

  2- The envelop and frequency for carrier signal were not affected.

  3- The envelop for DSB signal waves envelop close together if deceased or move away from each other if increases. in addition to, their frequency changed by:

  (fc-fm , fc+fm) =>(10000-500, 10000+500)

  (-fc-fm , -fc+fm) =>(-10000-500,-10000+500)

  But their amplitude was not affected.

  4- The change in fm that affected on upper/lower cut off frequency for filter

  lowcut_usb = fc+(fm/2) highcut_usb = fc+(3fm/2)

  so this affects the shape of the filter.

5- As a result of s(t) for DSB-SC change so s(t) for SSB-SC will change, Because the SSB-SC signal is the same of DSB-SC signal, but instead of having a two side band there is one side band -(upper side band or lower side band)- because it passed on filter.

6- As we can see in the last part of the figure above that the signal coming out from filter is similar to the massage sent. But, there are some distortion, that can be disposed of by using amplifier. Also, the position of signal in frequency for recovered massage change because of the fm change. But the amplitude of frequency doesn’t affect.

2.2.2.2 <u>fc=5000 Hz</u>

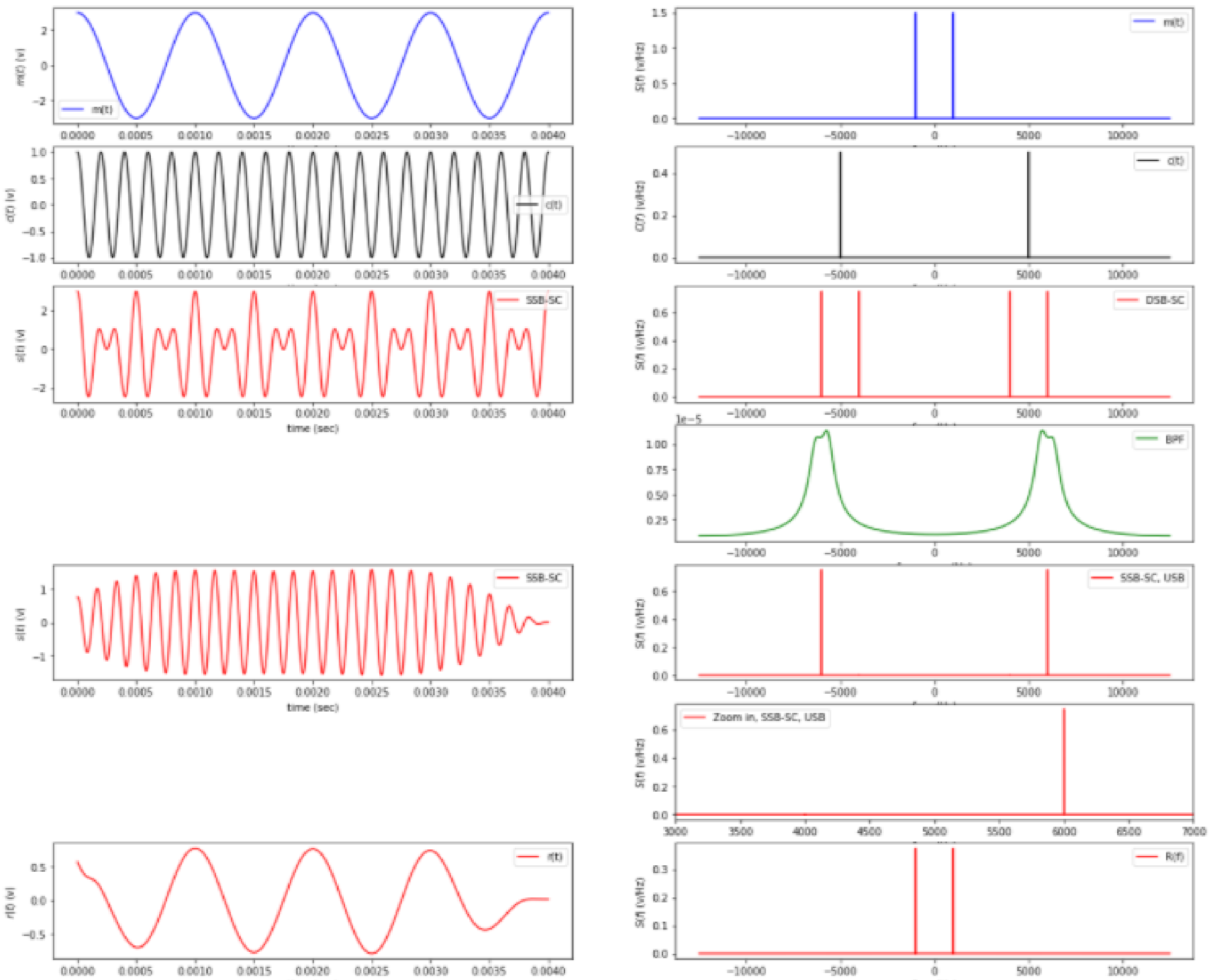


Figure 9:m(t), c(t), s(t) and r(t) in time and frequency domain with fc=5000 Hz

- **<u>Note</u>** When fc was decreased/increased:

  1- The envelop and frequency for massage signal were not affected.

  2- The envelop and frequency for carrier signal were affected.

  3- The envelop for DSB signal envelop wave 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.

  4- The upper and lower cut off frequency for filter change by:
  lowcut_usb = fc+(fm/2) highcut_usb = fc+(3fm/2)
  so this affects the shape of the filter.

5- As a result of s(t) for DSB-SC change so s(t) for SSB-SC will change, Because the SSB-SC signal is the same of DSB-SC signal, but instead of having a two side band there is one side band -(upper side band or lower side band)- because it passed on filter.

6- As we can see in the last part of the figure above that the signal coming out from filter is similar to the massage sent. But, there are some distortion, that can be disposed of by using amplifier. Also, the position of signal in frequency for recovered massage change because of the fc change. But the amplitude of frequency doesn't affect.

2.2.2.3 **Am=1.5 :**

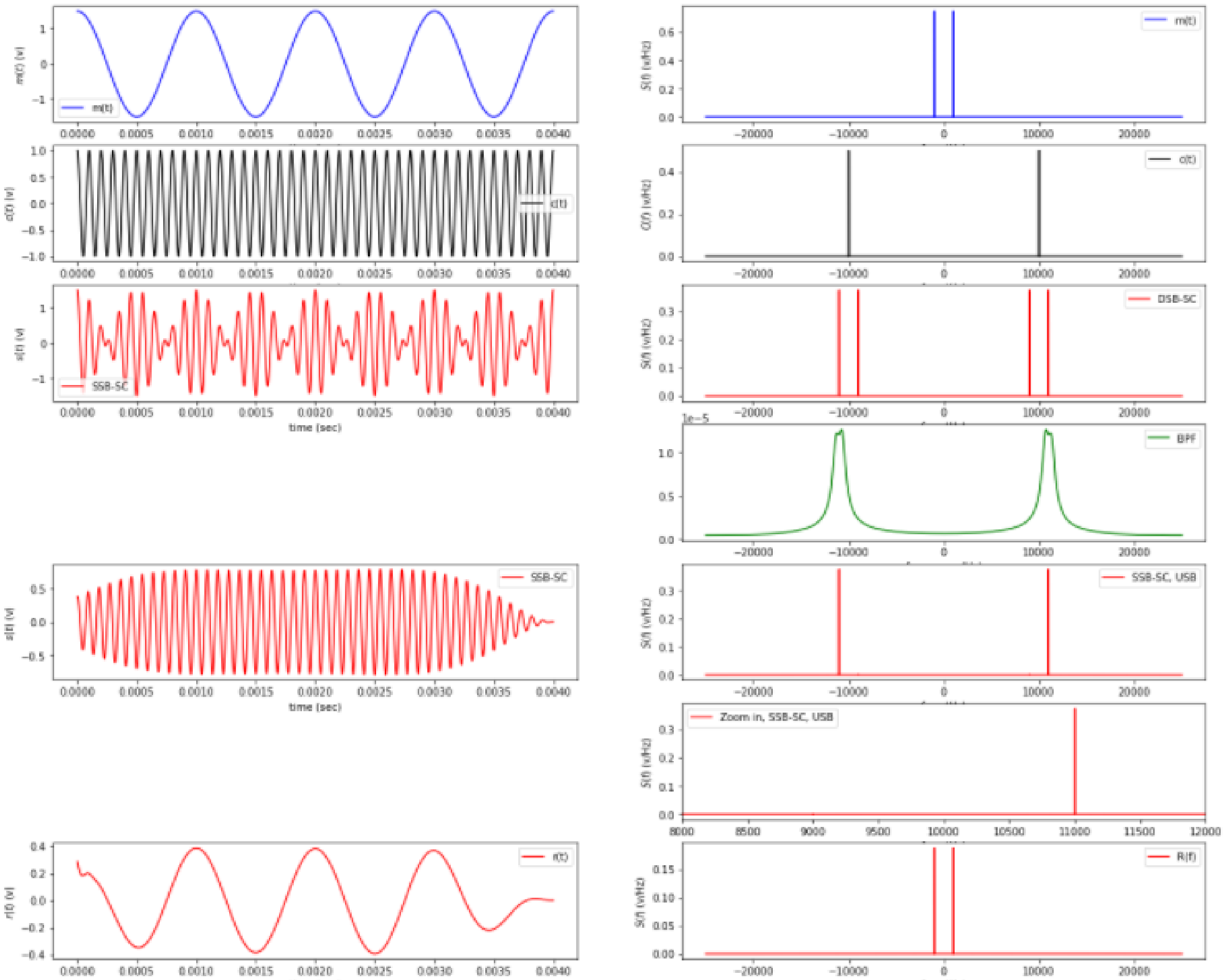


Figure 10:m(t), c(t), s(t) and r(t) in time and frequency domain with Am=1.5

- **Note**: When Am increased/decreased:
  1- The peak of the massage change (Am in time domain, (Am/2) in frequency domain) .
  2- The carrier envelop and frequency were not affected.
  3- The 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.
  4- The upper and lower cut off frequency for filter doesn't change so the shape of filter isn't affected.
  5- As a result of s(t) for DSB-SC change so s(t) for SSB signals will have the same change in time and frequency domain.

6- As we can see in the last part of the figure above that the signal coming out from filter is similar to the massage sent. But, there are some distortion, that can be disposed of by using amplifier. Also, the position of signal in frequency for recovered massage doesn’t change. But the amplitude of frequency affect by (Ac.Am/8).

2.2.2.4 Ac=2:

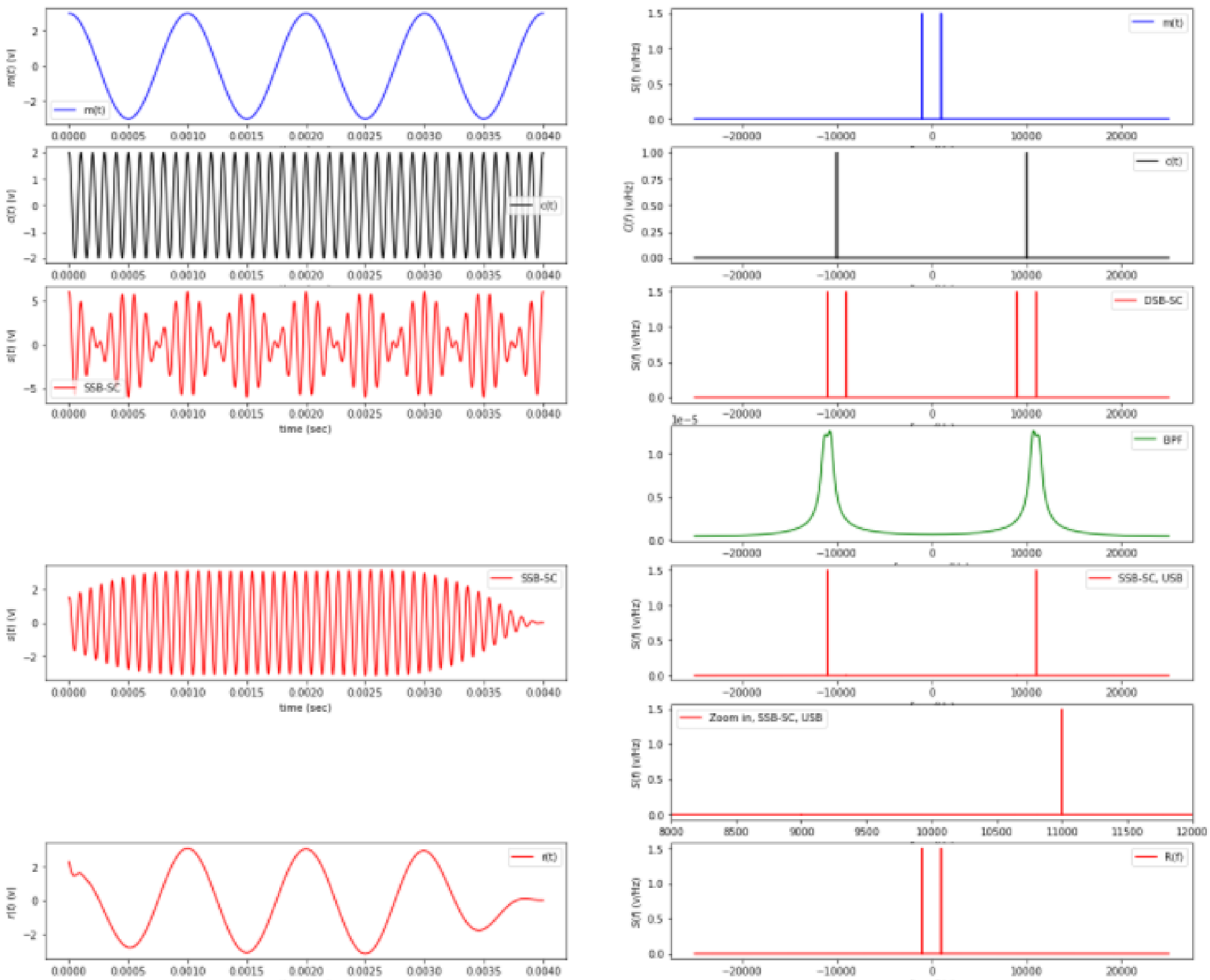


Figure 11:m(t), c(t), s(t) and r(t) in time and frequency domain with Ac=2

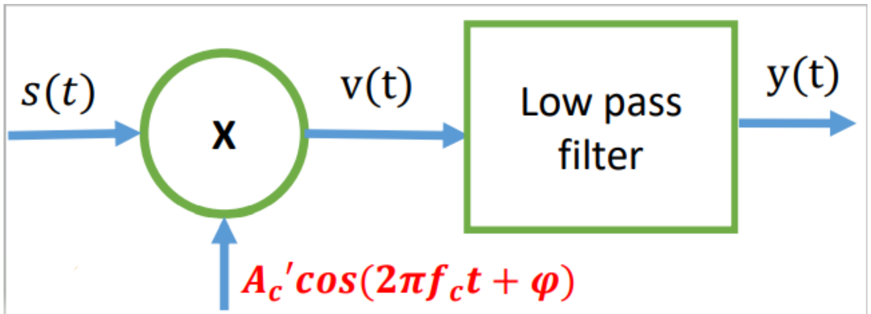
- **<u>Note:</u>** When Ac increased/decreased:
  1- The massage envelop and frequency were not affected.
  2- The peak of the carrier change (Ac in time domain, (Ac/2) in frequency domain) .
  3- The DSB signals envelope amplitude increases/decrees by (Am.Ac), While in frequency domain the amplitude of frequency change by ((Ac.Am) / 2), But the site that followed is not affected.

  4- The upper and lower cut off frequency for filter doesn't change so the shape of filter isn't affected.

5- As a result of s(t) for DSB-SC change so s(t) for SSB signals will have the same change in time and frequency domain.
6- As we can see in the last part of the figure above that the signal coming out from filter is similar to the massage sent. But, there are some distortion, that can be disposed of by using amplifier. Also, the position of signal in frequency for recovered massage doesn't change. But the amplitude of frequency affect by (Ac.Am/8).

2.3 SSB modulation/demodulation: effect of carrier noncoherence in phase on demodulated signal

2.3.1 Equation and result without any change:



where:

s(t): The modulated signal.

v(t): The demodulating signal.

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

$\varnothing$:phase shift.

$$y(t) = \frac{A_c \acute{A}_c}{2} m(t)\cos(\emptyset) + \frac{A_c \acute{A}_c}{2} \hat{m}(t)\sin(\emptyset)$$

Let:

```
Am1=3 # amplitude of message signal
fm1=1000 # frequency of message signal
Ac=1 # amplitude of carrier signal
fc=10000 # fequency of carrier signal
forder=2 # order of the filter
forder_LPF=5
Phi=80 #carrier noncoherence in phase
```

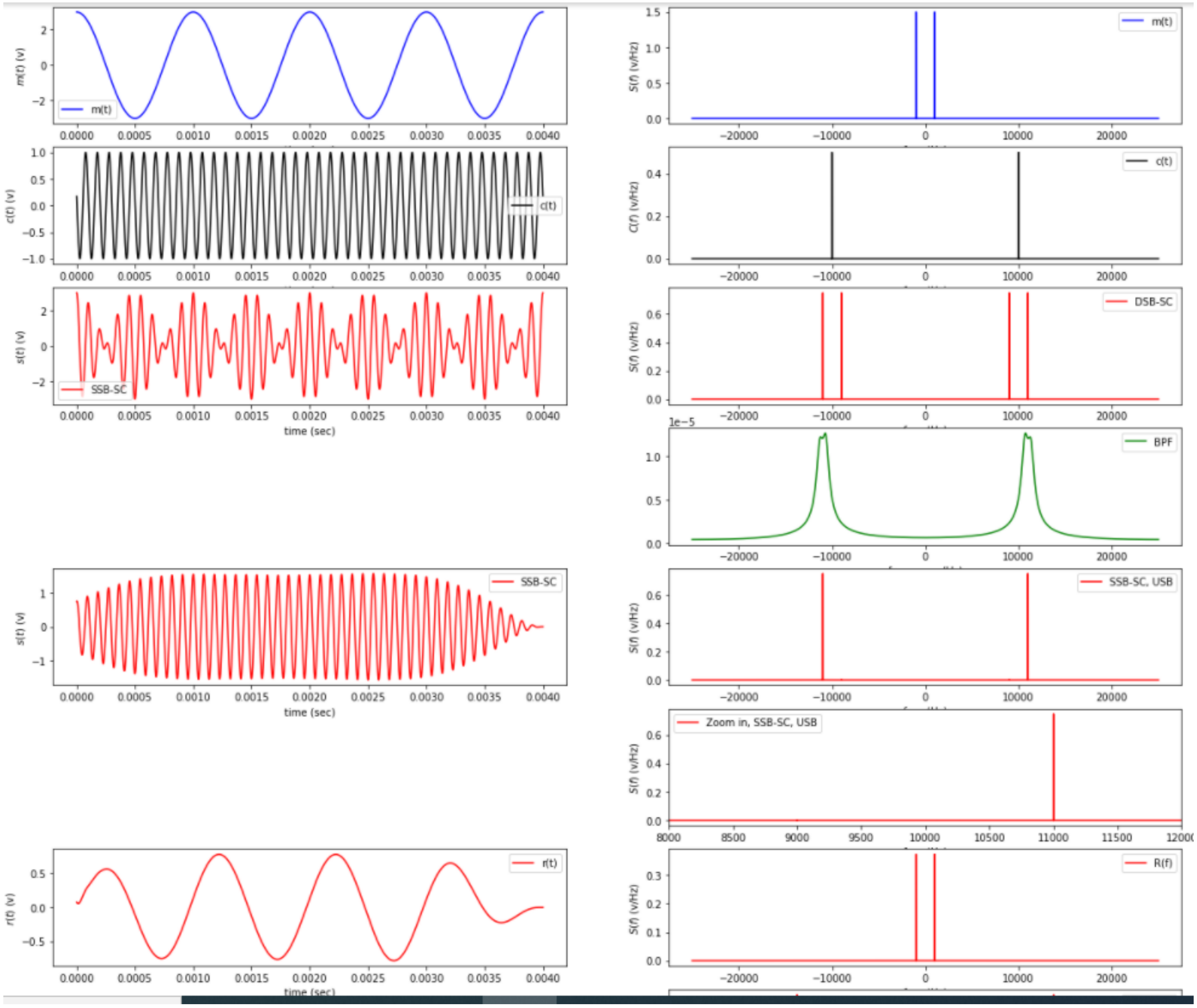


Figure 12:SSB-SC, effect of carrier noncoherence in phase on demodulated signal

- <u>**Note:**</u> in this case when (θ=80) we notice that recovered massage signal in time domain happened to it some attenuation as the amplitude changed and some of phase distortion. But until now, I can have recovered the massage by using amplifier.

2.3.2 <u>Exercise:</u>

2.3.2.1 <u>θ=85^0 :</u>

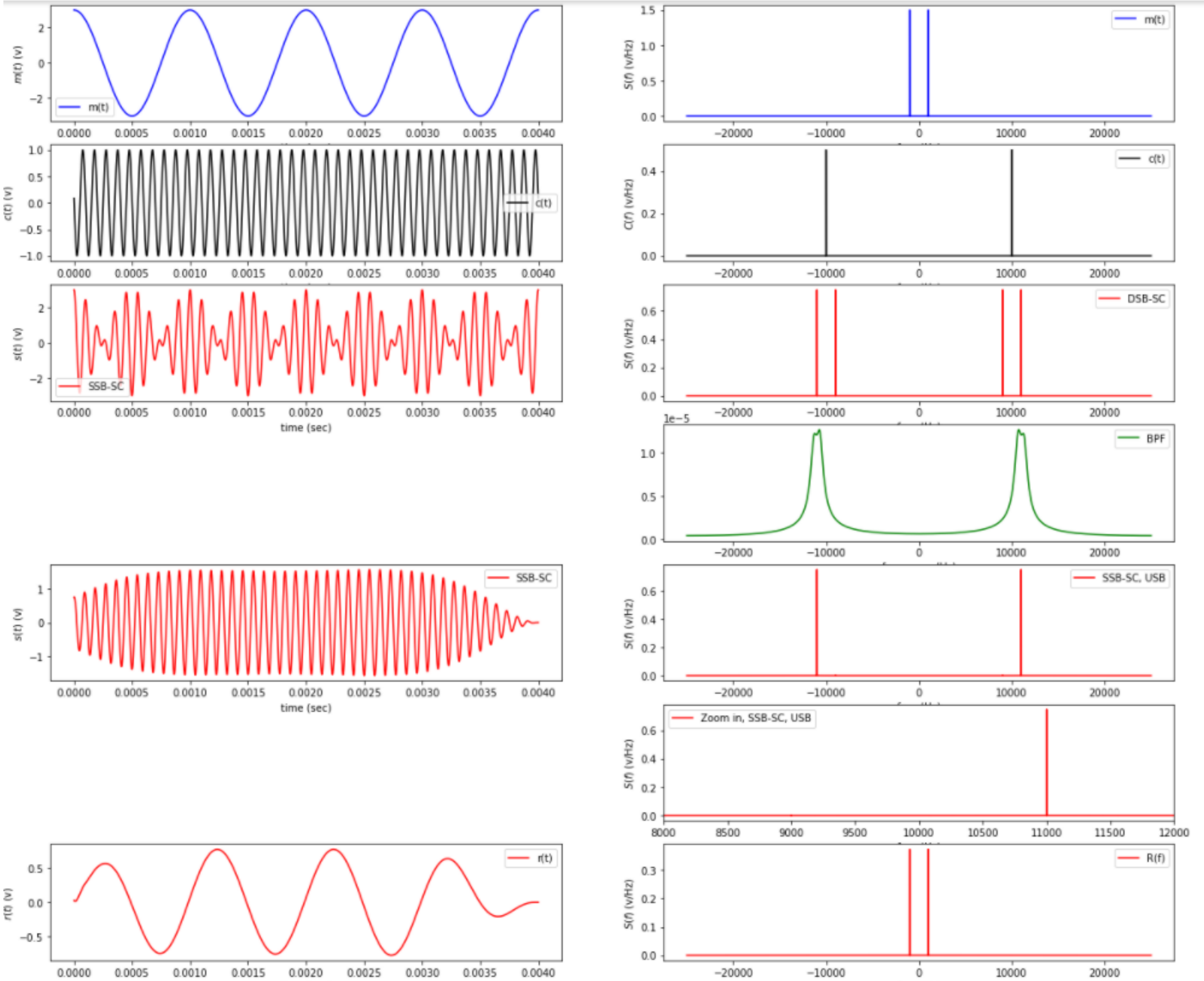


Figure 13:SSB-SC demodulation with carrier non coherence 85 -degree phase

- <u>**Note**</u>**:** When we increase the value of θ, we notice that recovered massage signal in time domain happened to it some attenuation as the amplitude changed and some of phase distortion. But until now, I can have recovered the massage by using amplifier.

2.3.2.2 $\theta=90^0$:

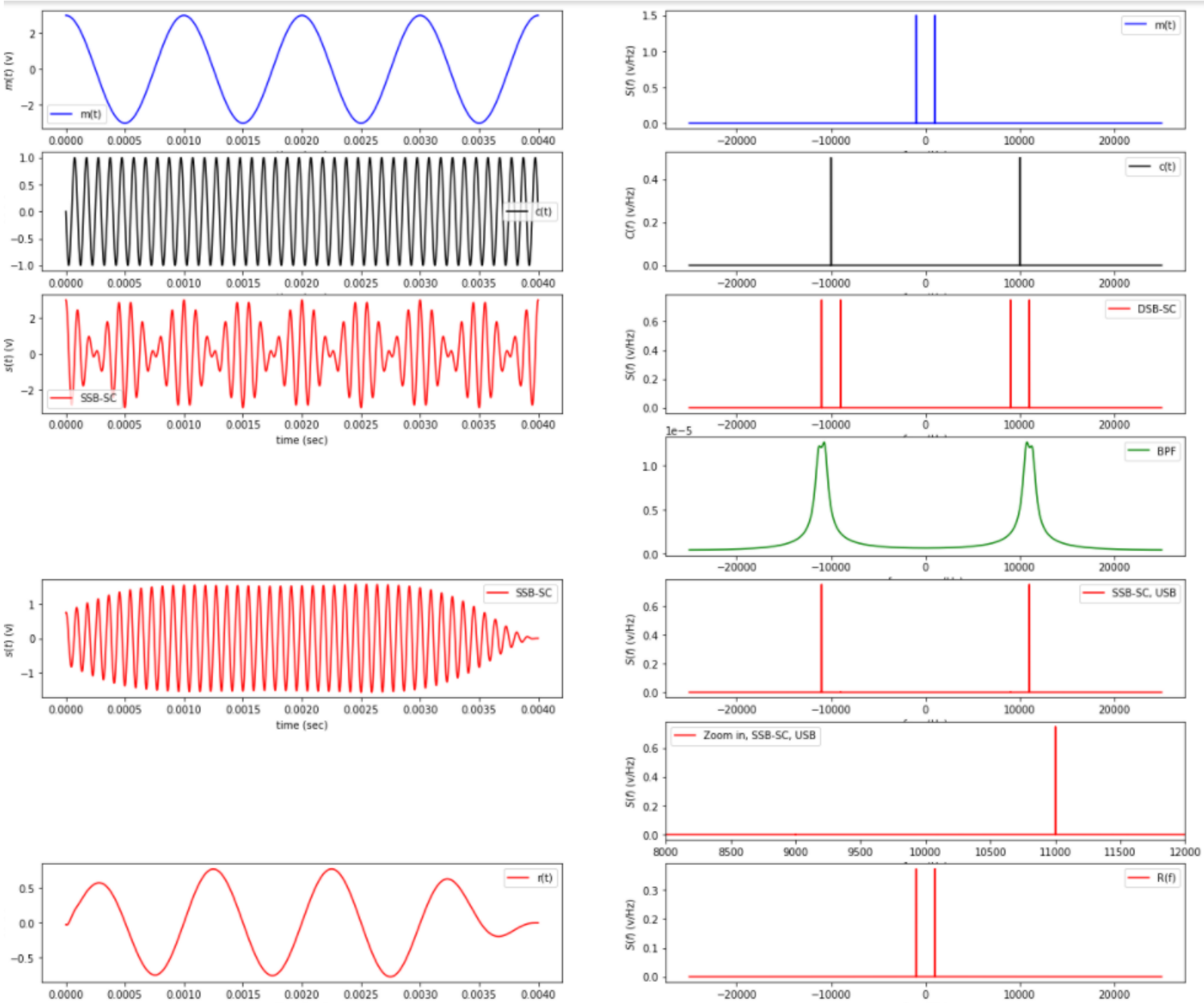
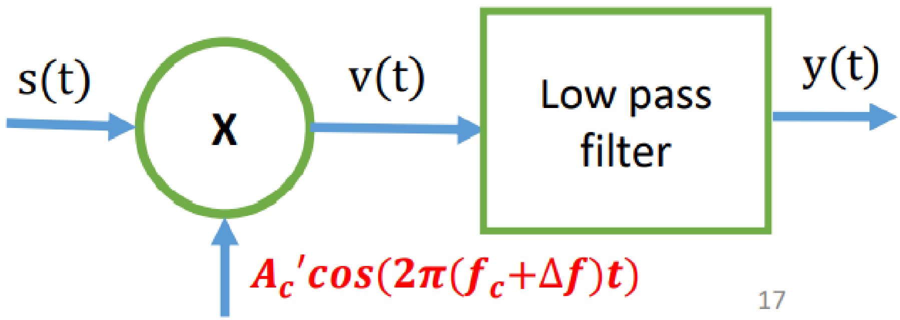


Figure 14:SSB-SC demodulation with carrier non coherence 90-degree phase

- **Note:** in this case when we increase the value of θ (θ=90), we notice that the recovered massage signal doesn't affected, and I can still recover the massage I sent it, because the output has cos component and sin component and when θ =90 the first component (cos 90 =0) so it loses but the second component (sin 90=1) remains present. And therefore, I can still have recovered the message was sent, but some attenuation in amplitude and shift happen to massage. And this thing is one of the advantages of SSB-SC that despite the change in angle, but I can still have recovered the massage signal.

2.4 SSB modulation/demodulation: effect of carrier noncoherence in frequency on demodulated signal

2.4.1 Equation and result without any change:



Where:

s(t): The modulated signal.

v(t): The demodulating signal.

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

Δf: Difference between fc and fc'

$$y(t) = \frac{A_c \acute{A}_c}{2} m(t) \cos 2\pi\Delta f t + \frac{A_c \acute{A}_c}{2} \hat{m}(t) \sin 2\pi\Delta f t$$

Let:

```
Am1=3 # amplitude of message signal
fm1=1000 # 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=2 # order of the filter
df=500 #carrier noncoherence in frequency
```

2.4.2 <u>Exercise:</u>

2.4.2.1 <u>df = 500 Hz :</u>

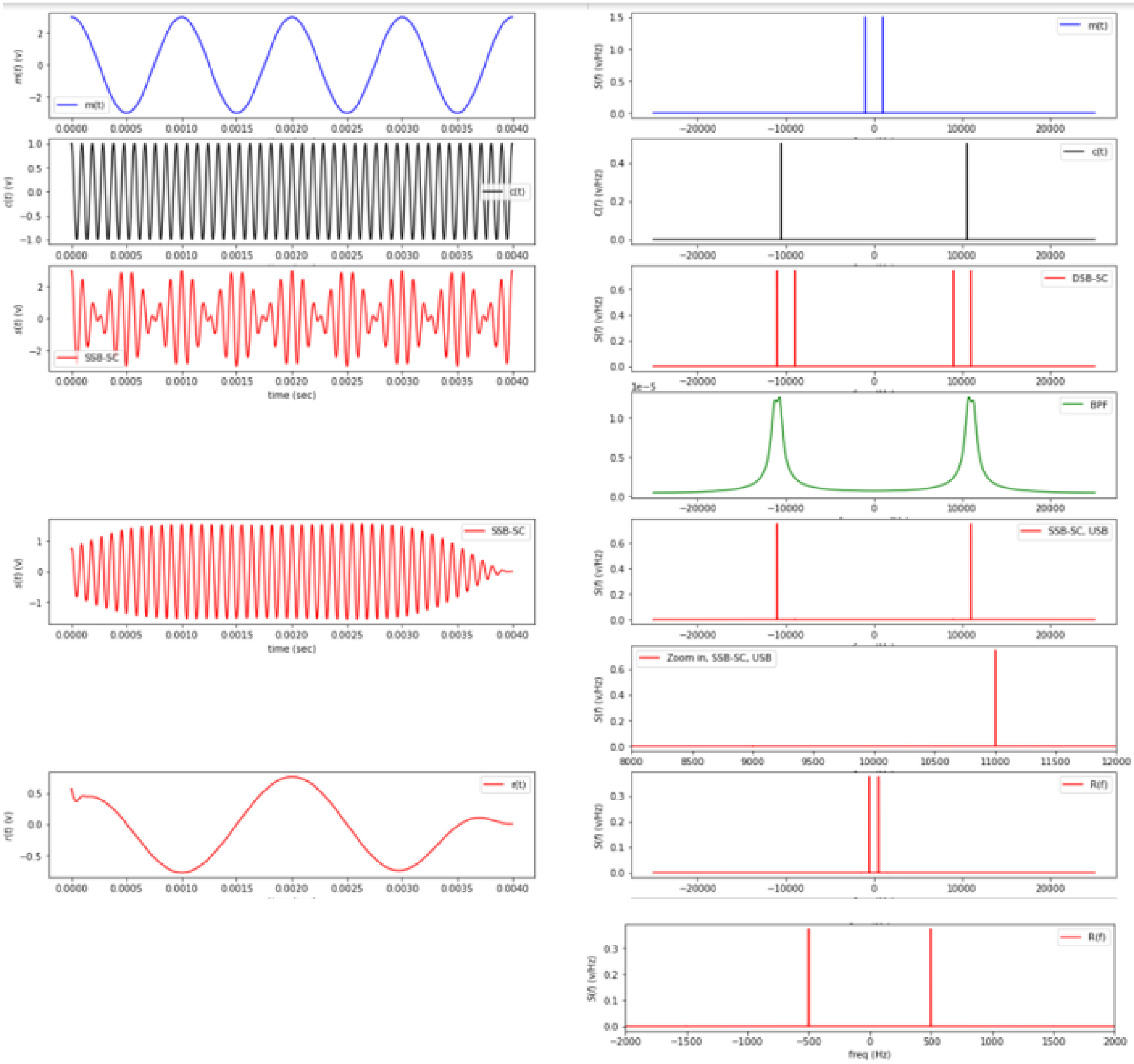


Figure 15:SSB-SC demodulation with df= 500 Hz

- **<u>Note:</u>** in this case we notice that recovered massage signal in time domain happened to it distortion and in frequency domain we notice the frequency change by (fm-df). 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.

2.4.2.2. df = 700 Hz :

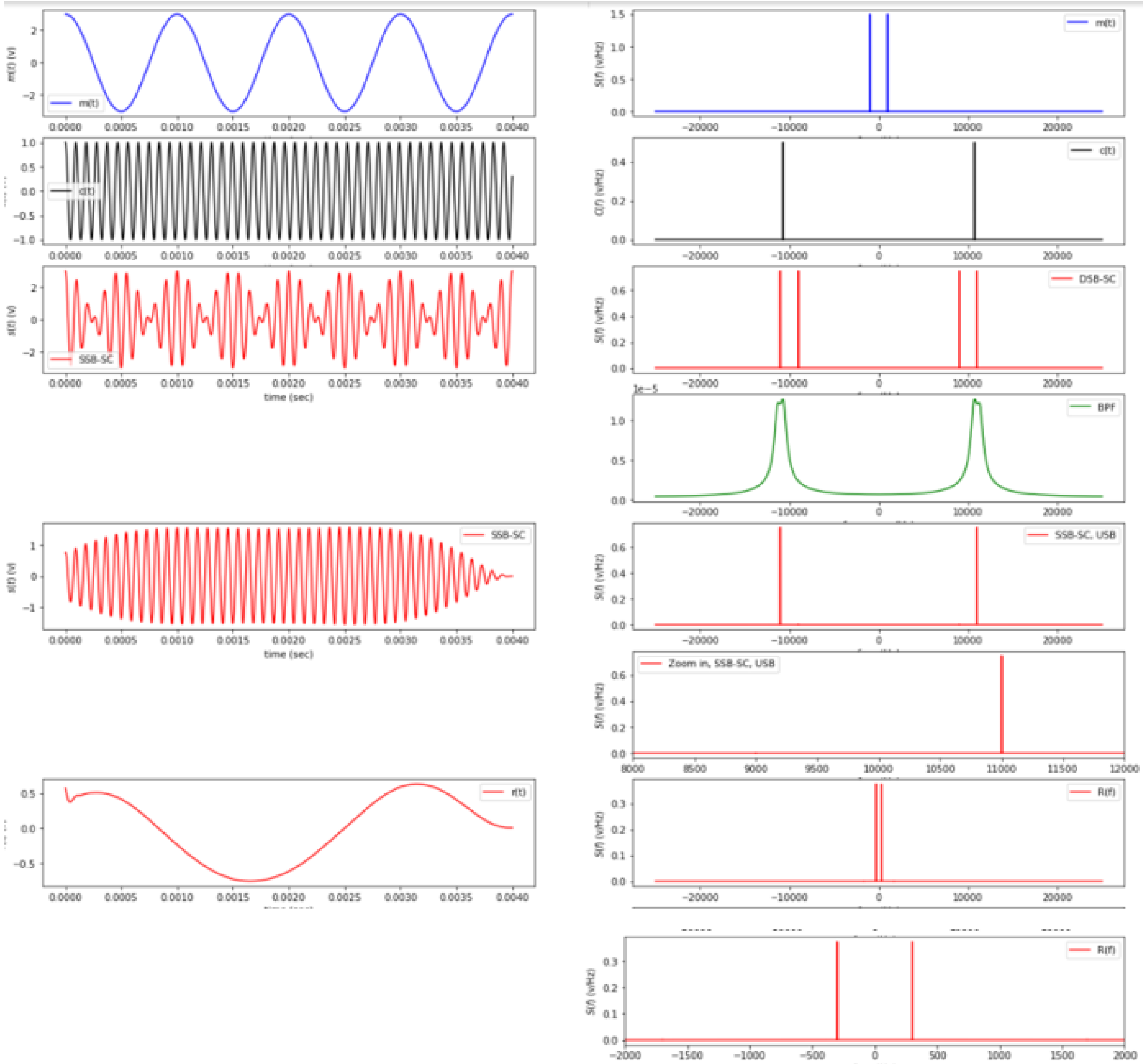


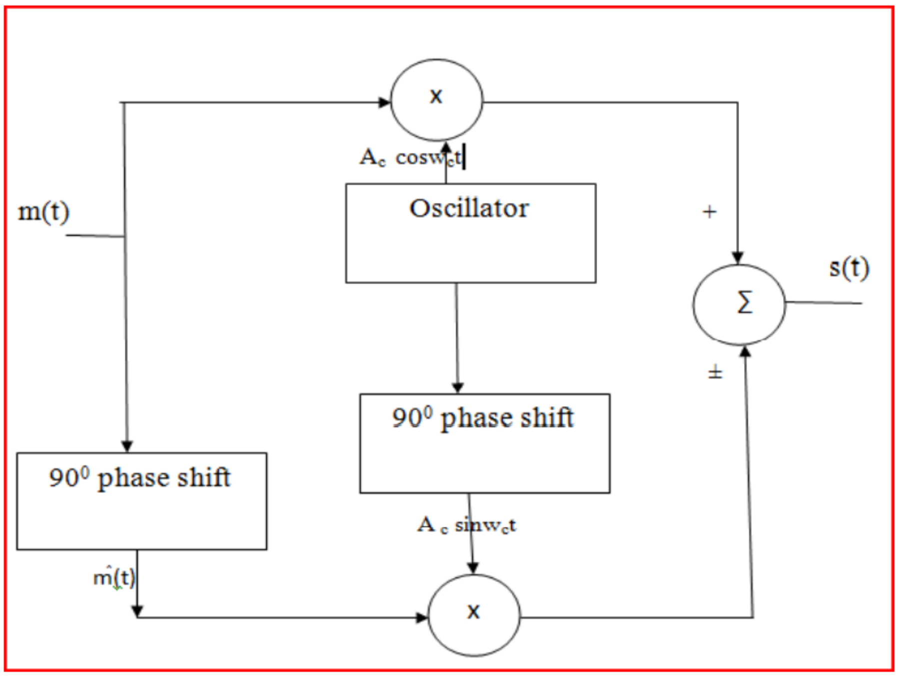
Figure 16:SSB-SC demodulation with df= 700 Hz

- **Note:** in this case when increase the df frequency we notice that recovered massage signal in time domain happened to it distortion and in frequency domain we notice the frequency change by (fm-df). 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.

2.5 Single Sideband in the time and frequency domains - Hilbert Transform:

2.5.1 Equation and result without any change:

$$s(t) = A_C m(t) cos\omega_c t \pm A_C \hat{m}(t) sin\omega_c t$$



where:

s(t): The modulated signal.

m(t): massage signal.

m(t)^: Hilbert transform massage signal.

Let:

```
Am1=3 # amplitude of message signal
fm1=5000 # fequency of carrier signal
Ac=1 # amplitude of carrier signal
fc=10000 # fequency of carrier signal
```

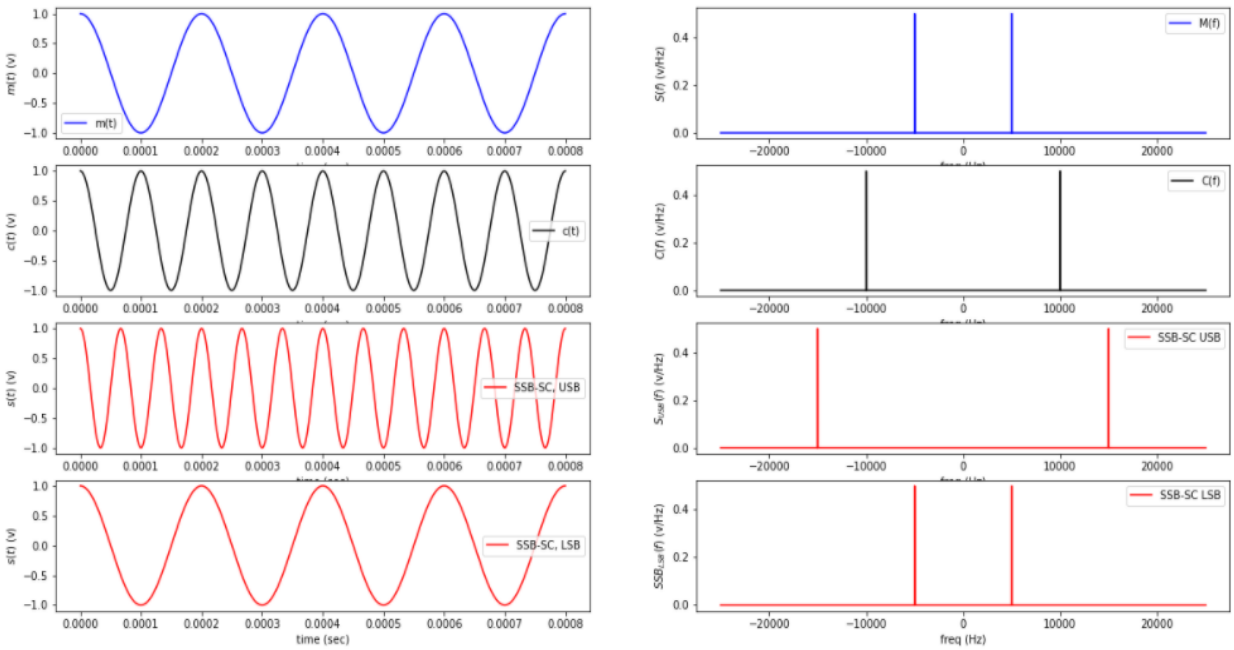


Figure 17:SSB-SC modulation by Hilbert transform

- **<u>Note:</u>** we notice from the above figure 4 graph the first one for massage signal, second for carrier signal , third for Hilbert transform to upper side and fourth graph to lower side.

2.5.2 **Exercise:**

2.5.2.1 **fm=1000 Hz :**

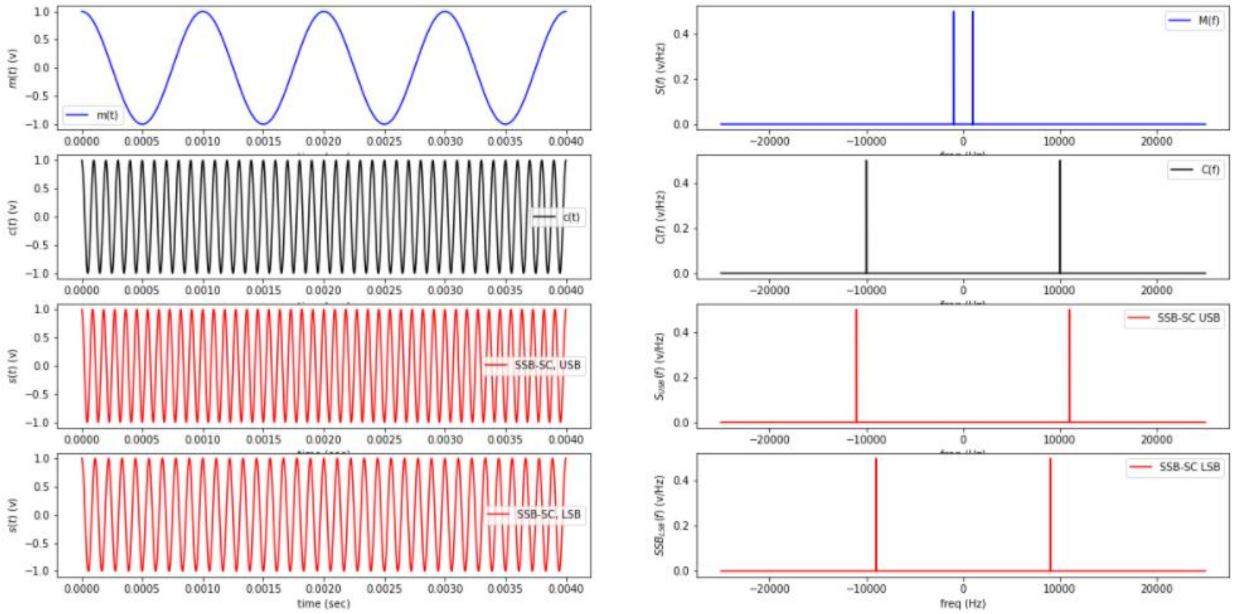


Figure 18:SSB-SC modulation by Hilbert transform with fm=1000 Hz

- **Note:** when fm was decreased/increase the envelop, BW and frequency for massage change. also carrier envelop and Hilbert transform (upper and lower) signal close together if deceased or move away from each other if increase. in addition to
  the SSB-SC USB signal frequency changed by:
  (-fc-fm , fc+fm) =>(10000-1000,10000+1000)
  and the SSB-SC LSB change by:
  (-fc+fm , fc-fm) =>(-10000+1000 , 10000-1000)
  But carrier frequency doesn't change and the amplitude for all signal don't change.

2.5.2.2 fc=12000 Hz :

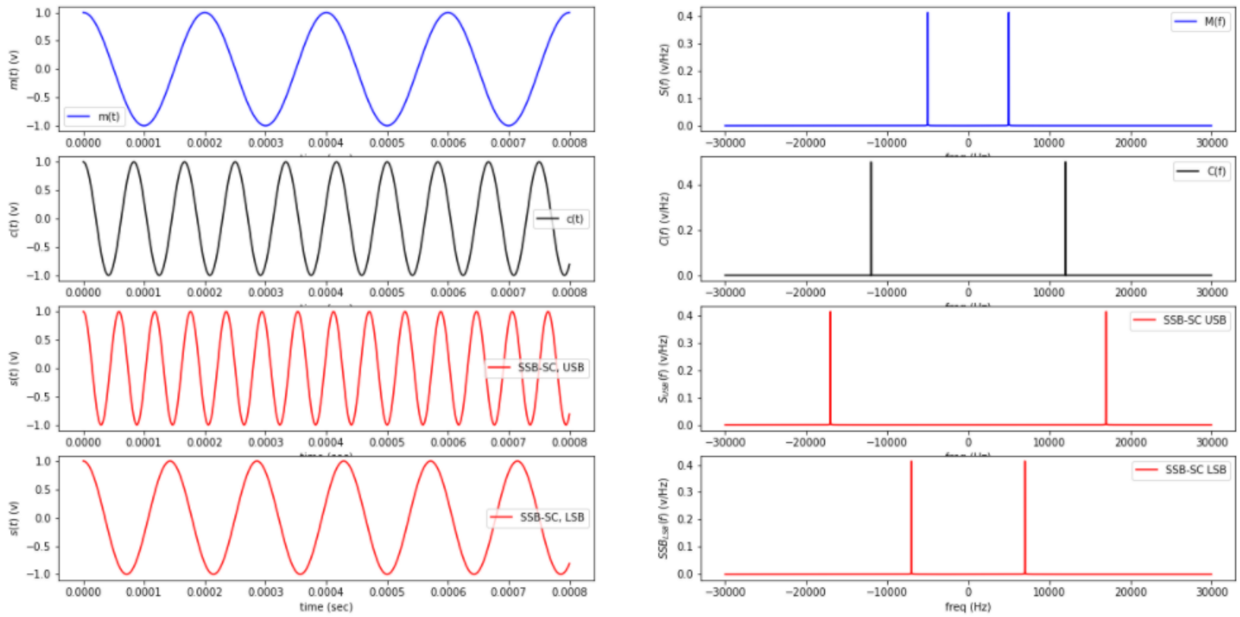


Figure 19:SSB-SC modulation by Hilbert transform with fc=12000 Hz

- **Note**: when fc was decreased/increase the envelop and frequency of massage signal were not affected. but waves for carrier envelop and Hilbert transform (upper and lower) signal waves expand and move away from each other if decreased or close together if increase. In addition to
  the SSB-SC USB signal frequency changed by:
  (-fc-fm , fc+fm) =>(12000-5000,12000+5000)
  and the SSB-SC LSB change by:
  (-fc+fm , fc-fm) =>(-12000+5000 , 12000-5000)
  But the amplitude for all signal don’t change.

2.5.2.3 Am=2:

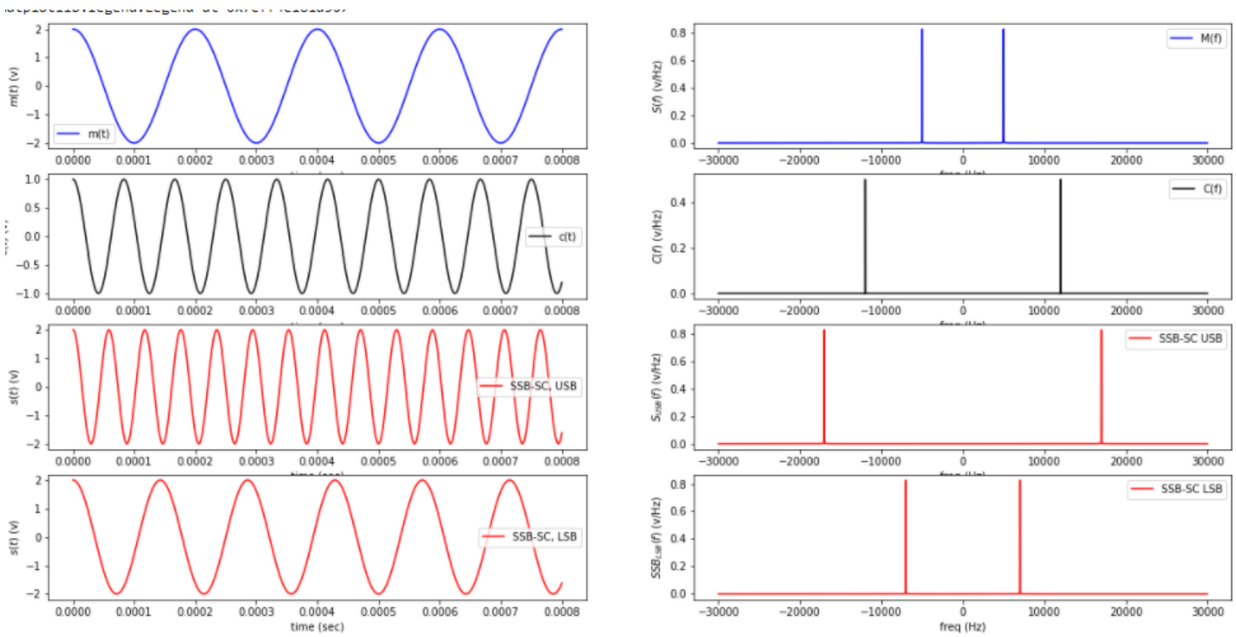


Figure 20: SSB-SC modulation by Hilbert transform with Am=2

- **Note**: when Am increased/decrees the peak of the massage signal change and Hilbert transform (upper and lower) signal change by (Am.Ac) in time domain . in addition to, massage amplitude frequency value changes by (Am/2) also for the upper and lower SSB-SC in frequency domain change by ((Am.Ac)/2). but the carrier envelop and frequency were not affected.

2.5.2.4 Ac=2:

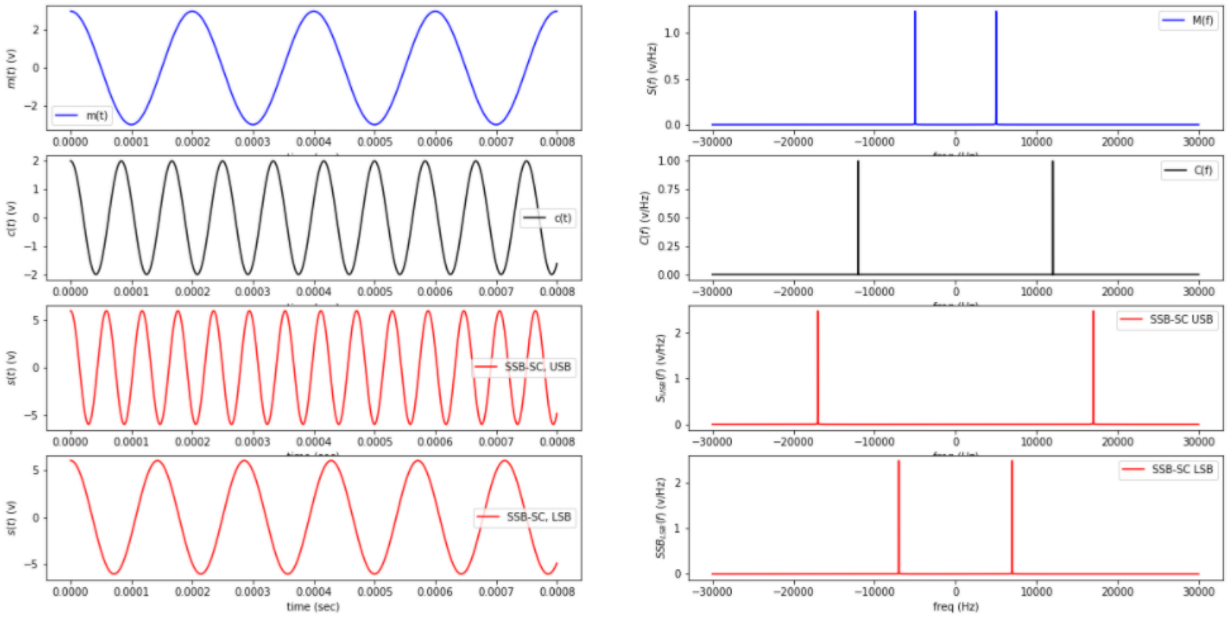


Figure 21:SSB-SC modulation by Hilbert transform with Ac=2

- **Note**: when Ac increased / decreased the peak of the carrier change and Hilbert transform (upper and lower) signal change by (Am.Ac) in time domain. in addition to, carrier amplitude frequency value changes by (Ac/2) also for the upper and lower SSB-SC in frequency domain change by ((Am.Ac)/2). But the massage envelope and frequency doesn’t change.

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.