BERZIET UNIVERSITY

FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ENEE 4113

communication Laboratory.

Experiment 1

AM Modulation and Demodulation

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Section # : 3

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❖ Part 1: Normal AM in the time and frequency domain:

In Normal AM, the formula of the modulated signal is shown below:

$$S(t) = Ac(1 + Ka\, m(t))Cos\, 2\pi fct$$

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.
K_a: Constant that represents the modulation sensitivity.

The envelope of S(t) is defined as:

$$A(t) = |Ac\,(\,1 + Ka\, m(t)\,)|$$

The message signal is :

$$m(t) = Am\; Cos\, 2\pi fmt$$

Where:
m(t): message signal.

A_m: The amplitude of the massage signal.
f_m: The frequency of the massage signal.

- Notice that the envelope of s(t) has the same shape as m(t) provided that it mustbe positive for a distortion-less demodulation using coherent detector.

Let :

```
Am = 1 # amplitude of message signal
Fm = 1000 # frequency of message signal
Ac = 1 # amplitude of carrier signal
Fc = 10000 # frquency of carrier signal
Ka = 0.5 # amplitude sensitivity
```

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

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

$s(t)=1[1+0.5.1.\cos(2\pi(1000)\,t)]\cos(2\pi 10000t)$

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

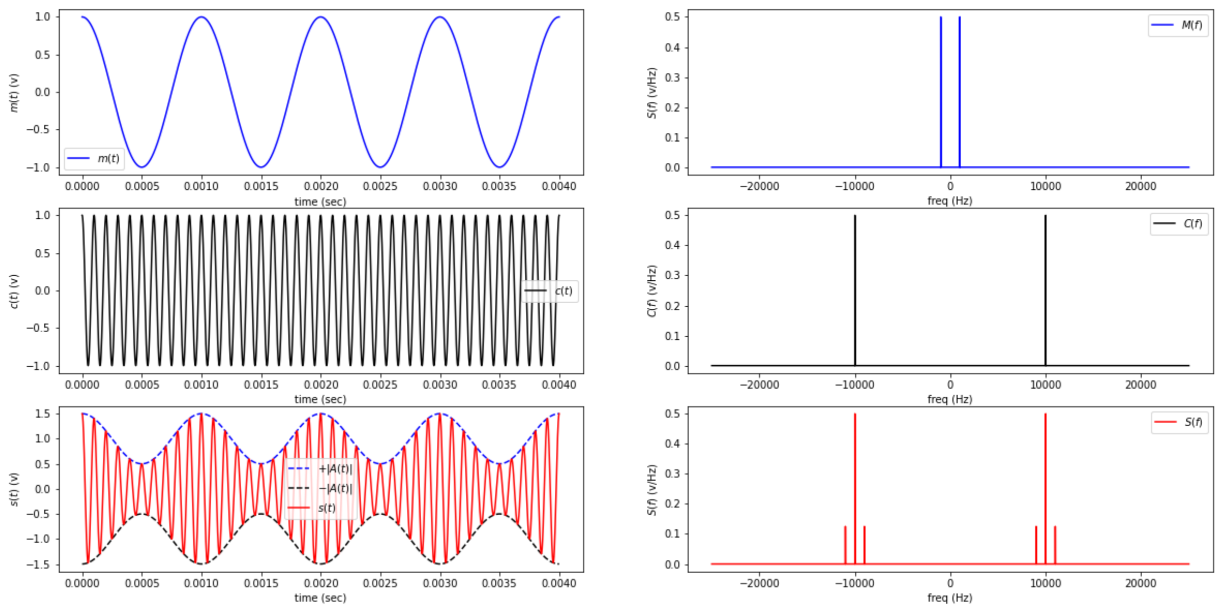


Figure 1: m(t), c(t), s(t) in time and frequency domain

- **<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) –AM modulation signal- signal That depend on m(t) and c(t).

Exercise:

The parameters of the signal were varied as following

1- fm = 500 Hz

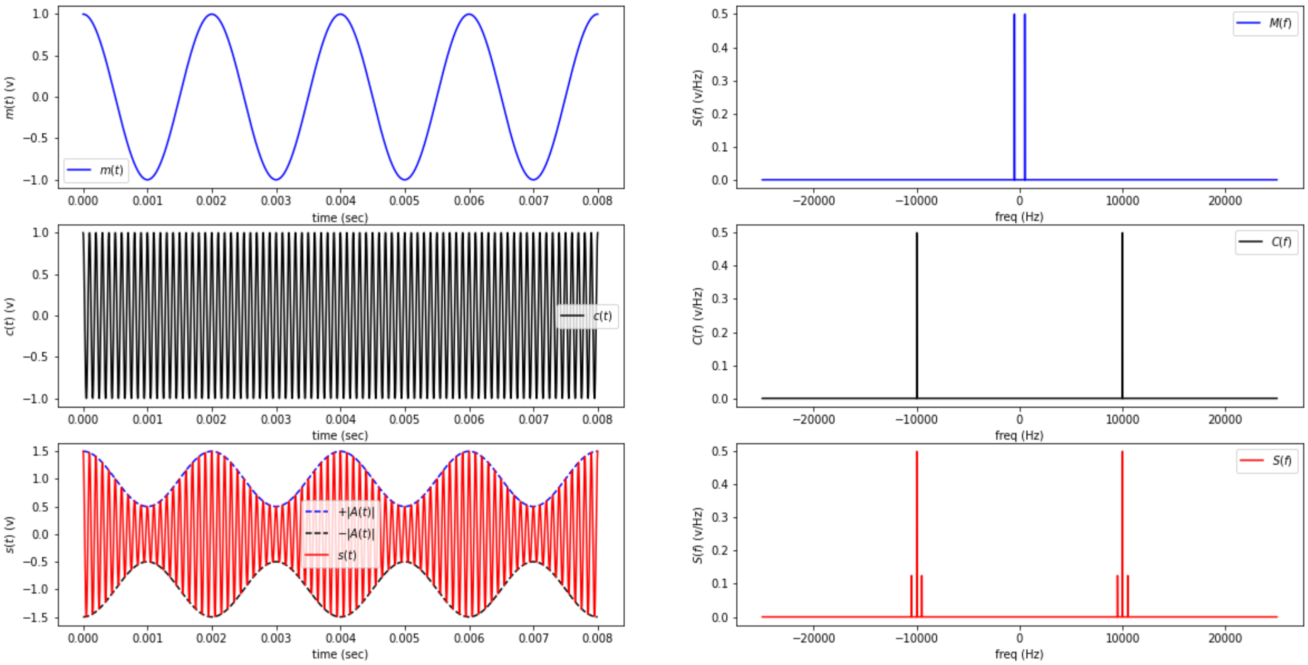


Figure 2:m(t), c(t), s(t) in time and frequency domain with fm = 500

- **Note:** when fm was decreased/increase the waves for massage change . also carrier envelop and AM signal close together if deceased or move away from each other if increase . in addition to the AM signal frequency changed by

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

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

  But carrier frequency doesn’t change.

2- fc=5000 Hz :

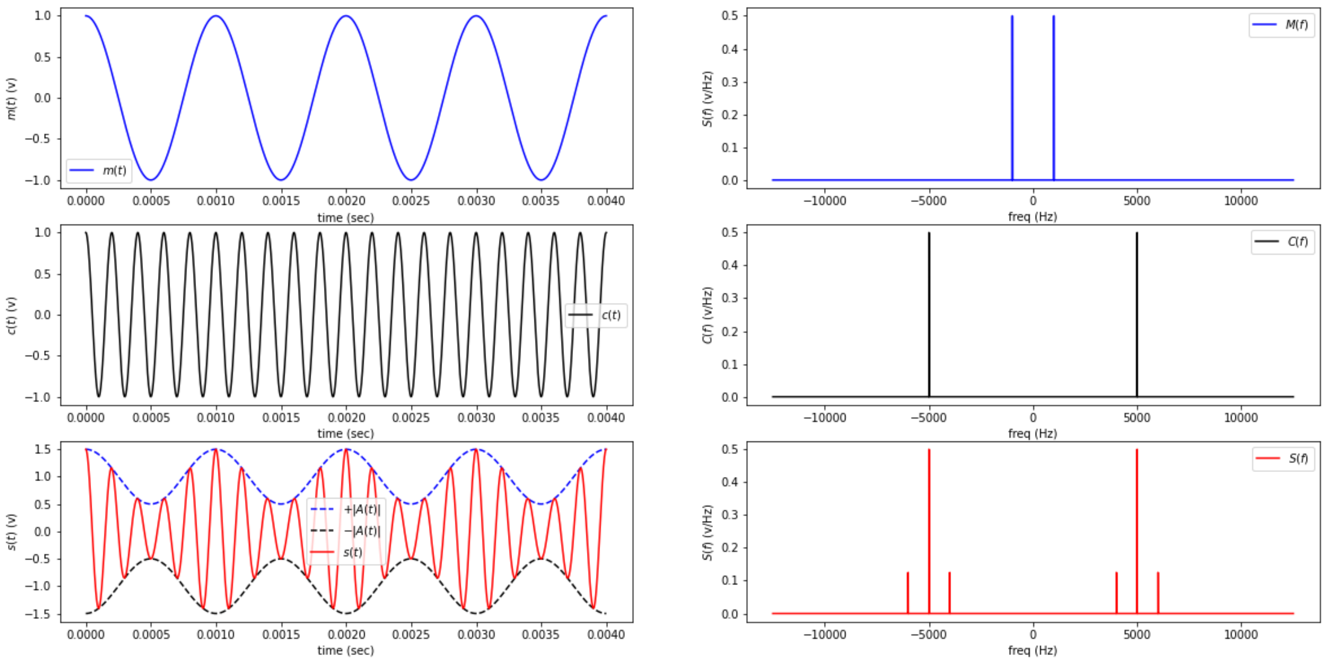


Figure 3: m(t), c(t), s(t) in time and frequency domain with fc = 5000

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

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

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

3- Am = 2:

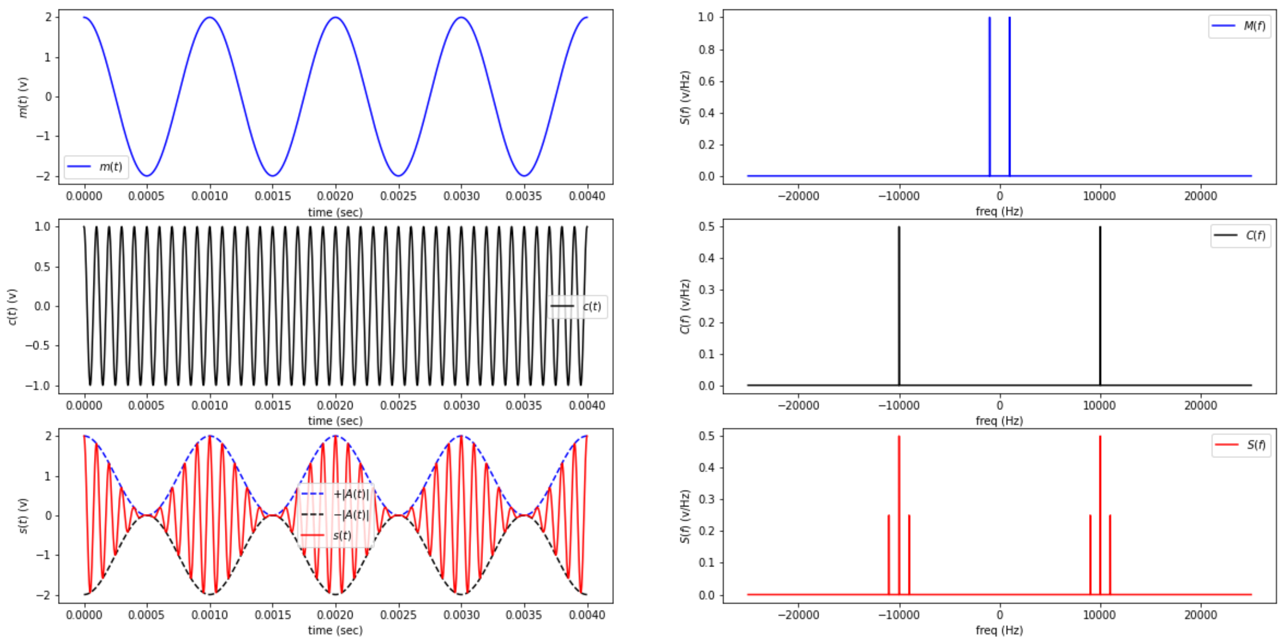


Figure 4:m(t), c(t), s(t) in time and frequency domain with Am = 2

- **<u>Note</u>:** when Am increased/decrees the peak of the massage increases and AM signals envelope increases/decrees by (Ac+(Ac.Am.Ka)). in addition to, massage amplitude frequency value changes by $(A_m/2)$ also for the upper and lower parts in AM frequency change by $(A_m\ \mu/4)$. but the carrier envelop and frequency were not affected.

4- Ac = 2

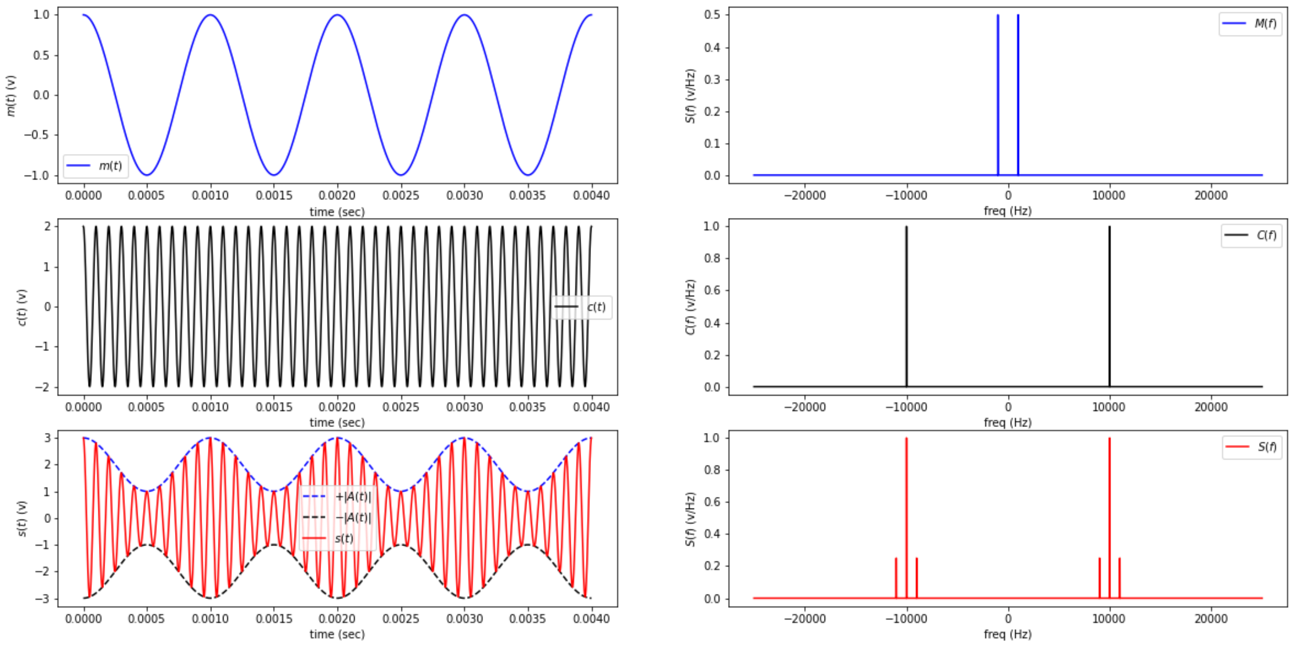


Figure 5: m(t), c(t), s(t) in time and frequency domain with Ac = 2

- **Note:** when Ac increased / decrease the peak of the carrier increases / decrease and AM signals envelope increases / decrease by (Ac+(Ac.Am.Ka)). in addition to, carrier amplitude frequency value changes by (A_c/2). But the massage envelope and frequency doesn’t change

5- Ka=1:

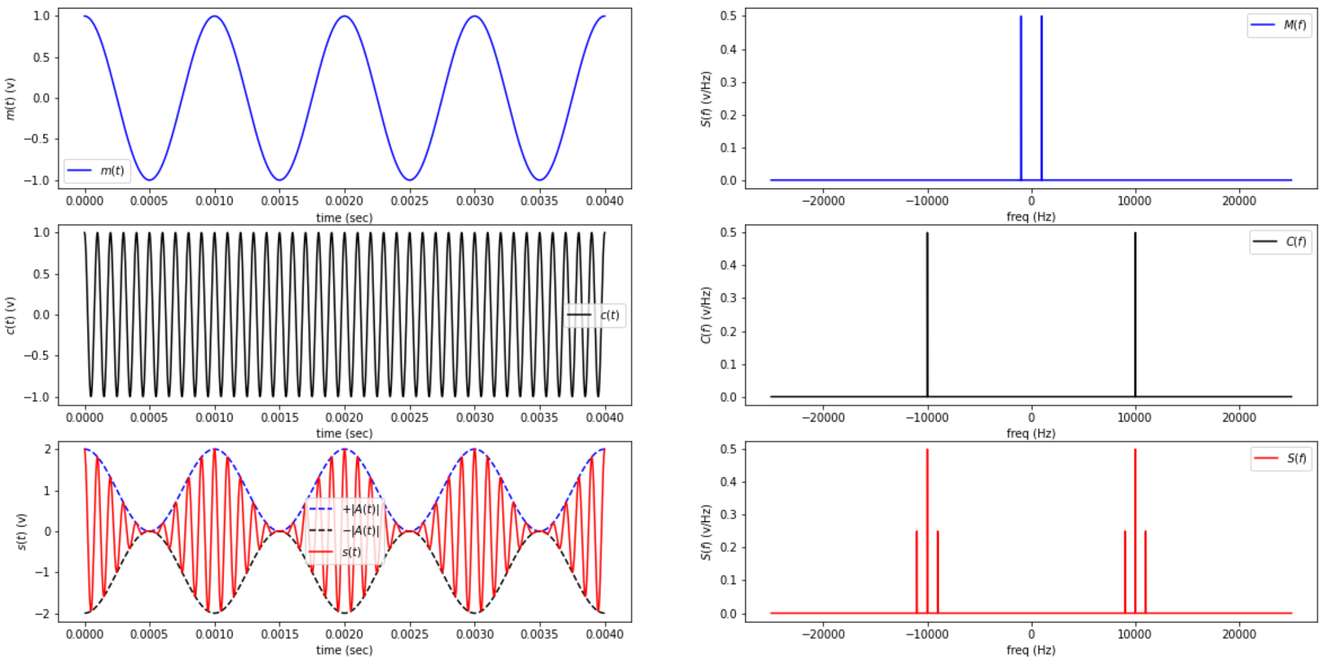


Figure 6: m(t), c(t), s(t) in time and frequency domain with Ka = 1

- **<u>Note</u>:** when Ka increased/decrees the carrier and massage signals were not affected but AM signals envelope increases/decrease by (Ac+(Ac.Am.Ka)).).

❖ Part 2: The effect of changing the AM modulation index μ:

Then a new constant called The modulation index will appear:

$$\mu = Ka\ Am$$

where:

μ: modulation index , $0 < \mu < 1$

Ka: amplitude sensitivity

Am: amplitude of message signal

There are three cases depending on the modulation index (μ):

1- Under modulation when $0 < \mu < 1$

2- Over modulation when $\mu > 1$

3- Full modulation when $\mu = 1$

Let:

Am1=0.5 # amplitude of first message signal
Am2=1 # amplitude of second message signal
Am3=3 # amplitude of third message signal
fm=1000 # frequency of message signals
Ac=2 # amplitude of carrier signal
fc=10000 # frequency of carrier signal
Ka=1 # amplitude sensitivity

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

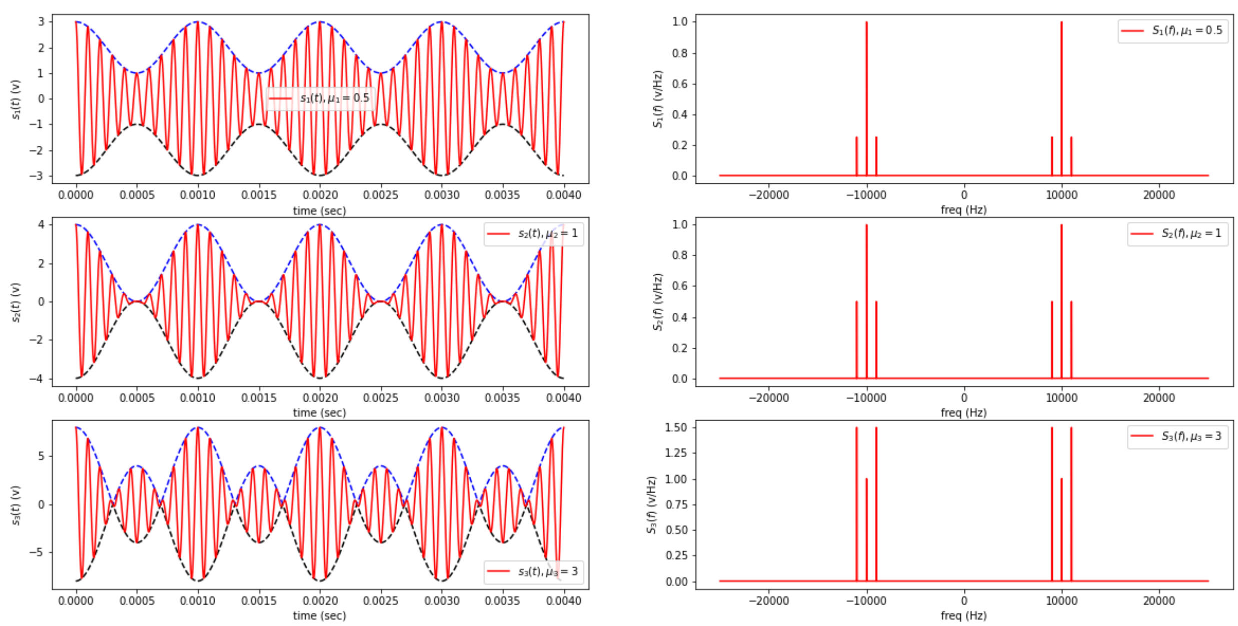


Figure 7: s(t) in time and frequency domain with varied Am

- **<u>Note:</u>**

1- the first figure from the above figure, <u>its under modulation signal</u> and this occurs when **$0<\mu<1 (\mu=0.5)$.** the envelope is represents message signal. And the power loss between the amplitudes (0.5 and 0) in this case

2- the second figure from the above figure, <u>its Full modulation signal</u> and this occurs when **$\mu=1$.** the envelope is represents message signal. And the power losses here is less than the under modulation case

3- the second figure from the above figure, its <u>over modulation signal</u> and this occurs when **$\mu > 1$.** In addition to an ideal envelop detector cannot be used to extract m(t) and distortion takes place.

Exercise:

1- Am1=0.3 , Am2=0.6 and Am3=0.5   Ka=2

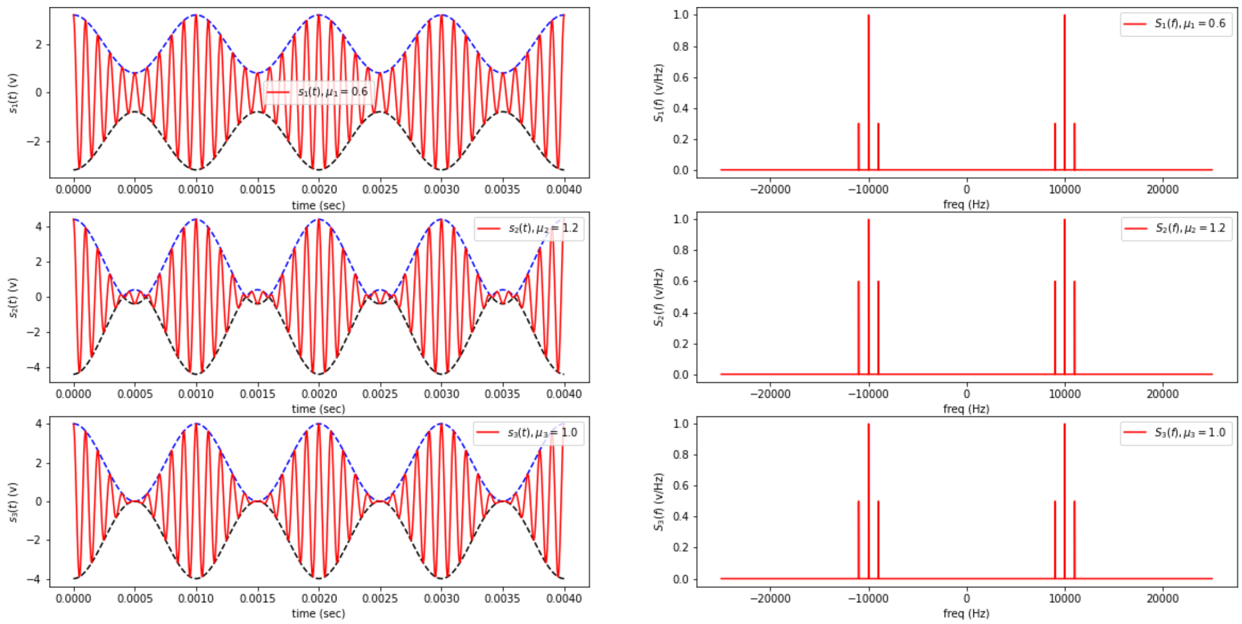


Figure 8: s(t) in time and frequency domain with varied Am1=0.3 , Am1=0.6 ,Am1=0.5 ,Ka=2

- **Note**: the over modulation occurs at μ > 1 which will change the envelope of the message signal and should be avoided . Also, when μ =1 , the envelope is represents message signal.

❖ Part3: Normal AM modulation of a message signal with multiple harmonics:

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

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 # frequency of message signal

Am2=2 # amplitude of message signal
fm2=2000 # frequency of message carrier 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
Ka=0.3 # amplitude sensitivity

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

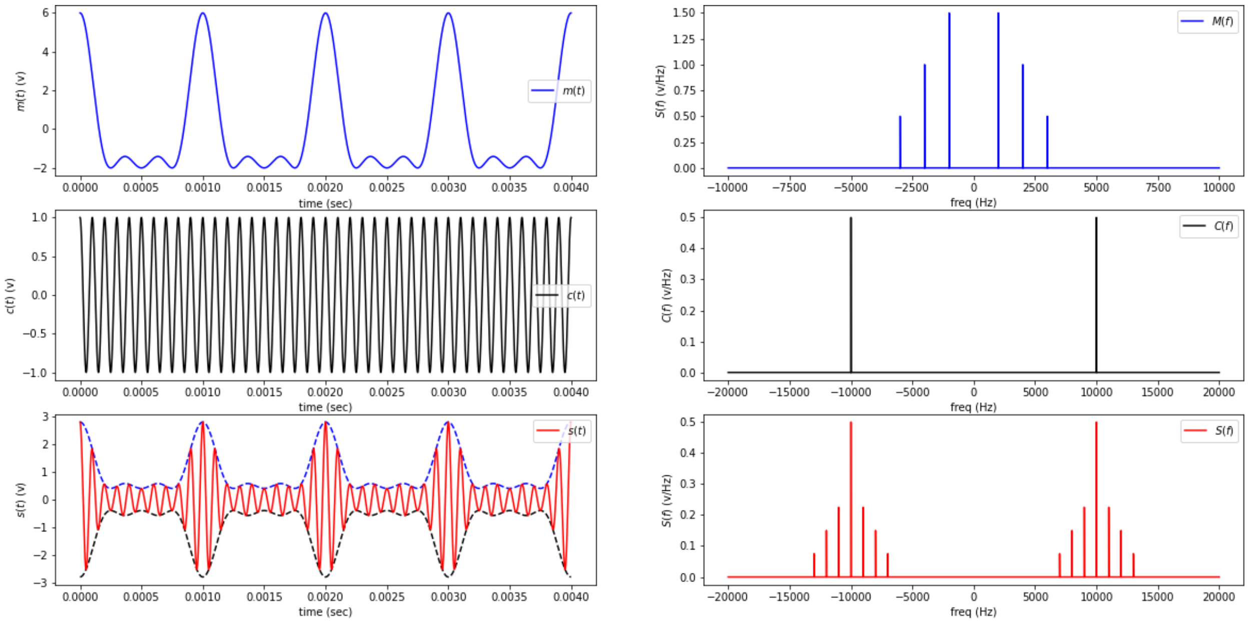


Figure 9: Normal AM modulation of a message signal with multiple harmonics

- **<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) –AM modulation signal- signal That depend on m(t) and c(t).

Exercise:

1- fm_1=500 , fm_2=1000 , fm_3=1500 :

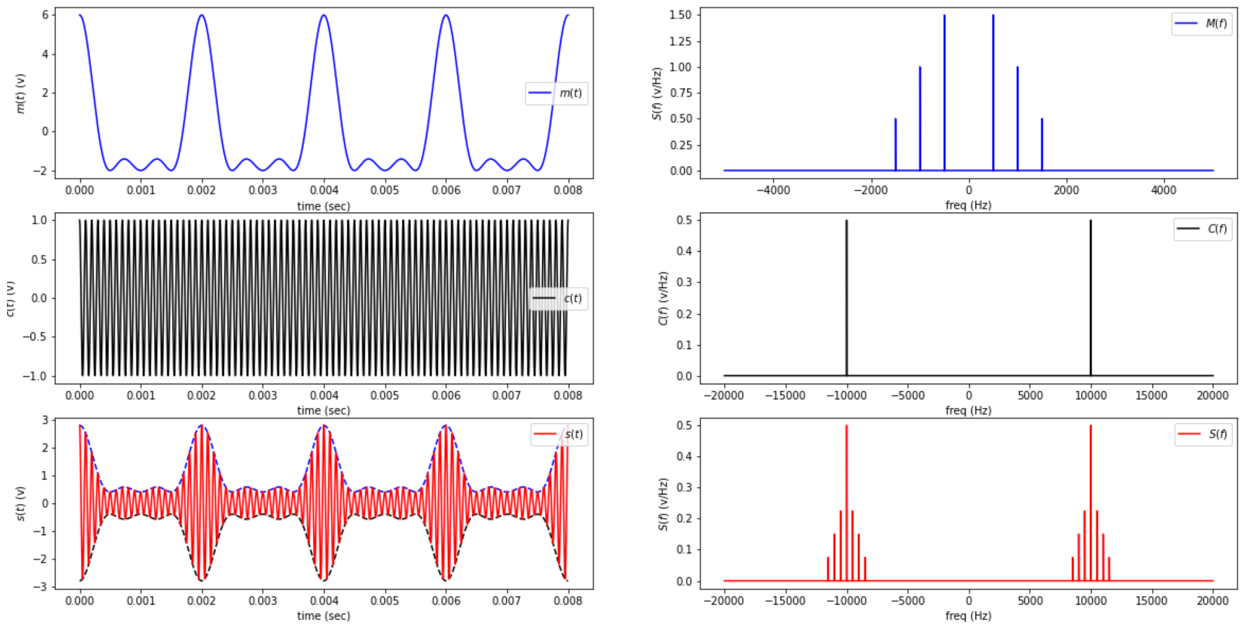


Figure 10: Normal AM modulation of a message signal with multiple harmonics(fm1=500,fm2=1000,fm3=1500)

- **<u>Note</u>**: when fm was change the waves for massage change . also the carrier envelop and AM signal waves expand and move away from each other if fm decreased or close together if fm increase. in addition to the AM signal frequency between the carrier frequency changed by :

  (fc-fm , fc , fc+fm) and (-fc-fm , -fc , -fc+fm)

  But the carrier frequency doesn't change.

2- fc=8000 Hz

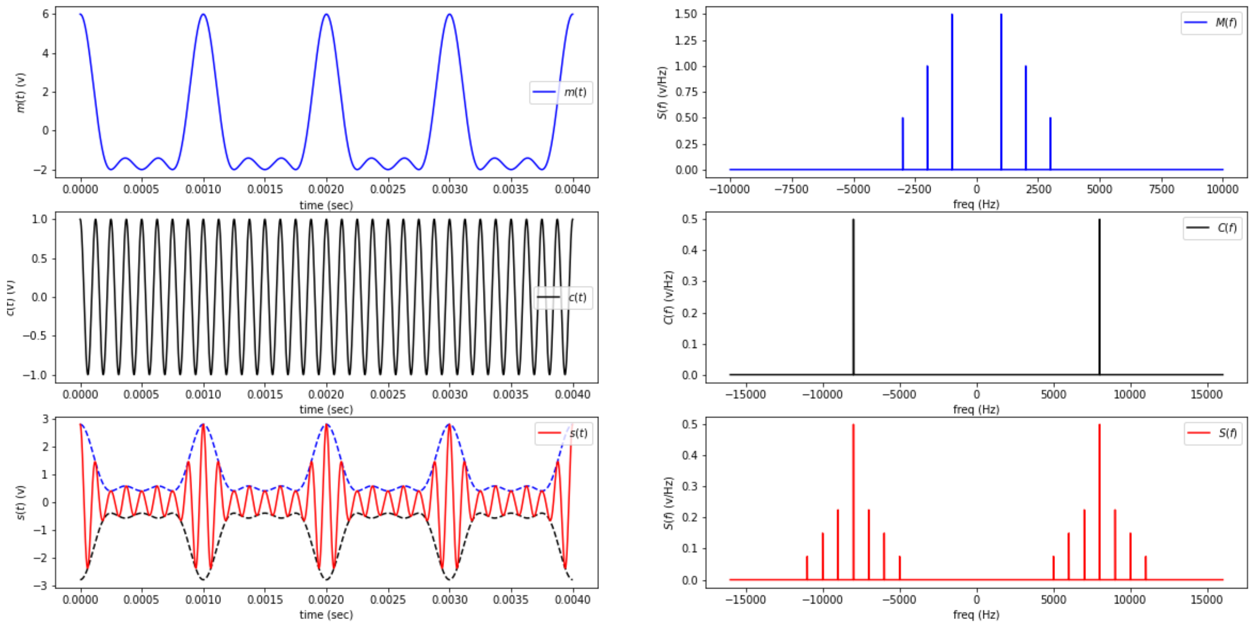


Figure 11: Normal AM modulation of a message signal with multiple harmonics fc=8000

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

3- Am_1=2 , Am_2=4 , Am_3=0

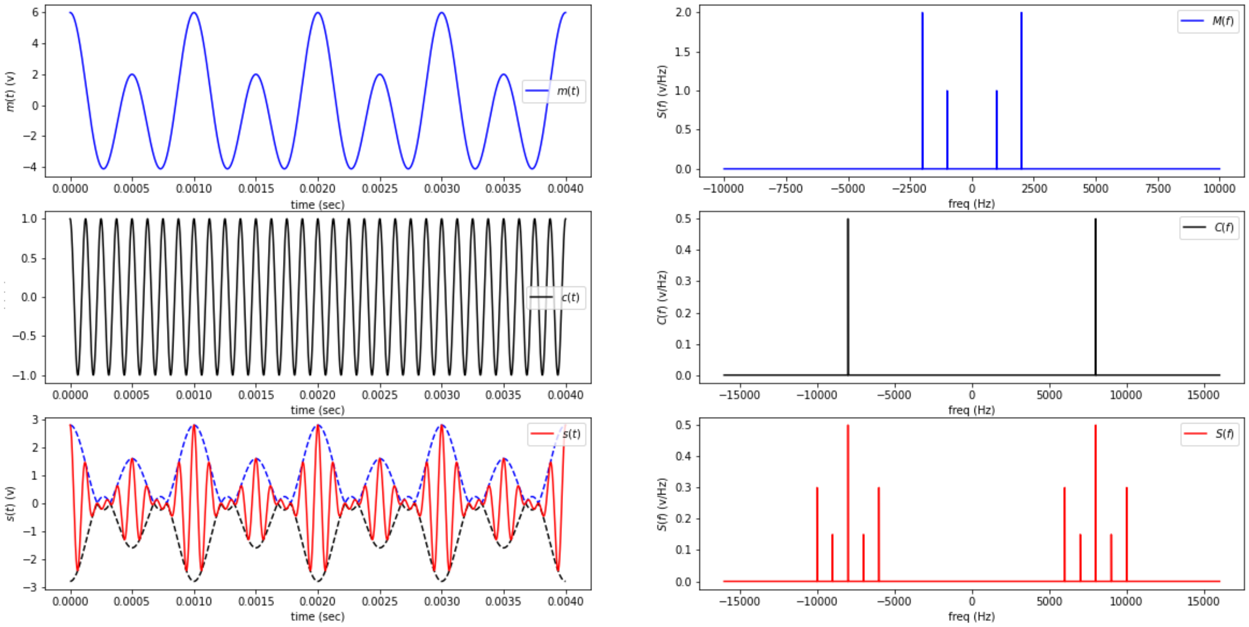
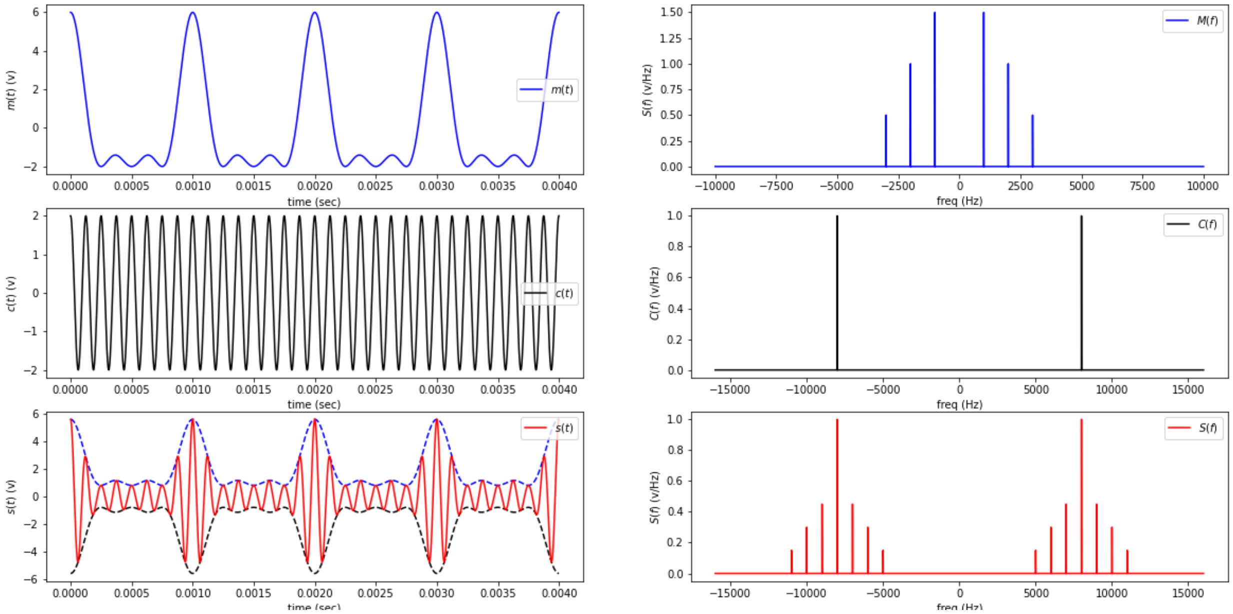


Figure 12: Normal AM modulation of a message signal with multiple harmonics(Am1=2,Am2=4,Am3=0)

- **<u>Note</u>:** At the beginning, we notice when we put (Am_3=0) this massage (m_3) has disappeared. Also, when Am increased the peak of the massage increases and AM signals envelope increases by (Ac+(Ac.Am.Ka)). in addition to, massage amplitude frequency value changes by ($A_m/2$) also for the upper and lower parts in AM frequency change by (A_m $\mu/4$) . but the carrier envelop and frequency were not affected.

4- Ac=2



- **<u>Note</u>:** when Ac increase/decrees the peak of the carrier increases/decreases and AM signals envelope increases/decreases by (Ac+(Ac.Am.Ka)). in addition to, carrier amplitude frequency value changes by (A_c/2). But the massage envelope and frequency doesn’t change.

❖ Part 4: Demodulation of Normal AM:

$$1/fc < 1/\tau < 1/fm$$

Where:

fm: frequency of message signal
fc: frequency of carrier signal
τ: discharging time of capacitor

Let:

Am=0.5 # amplitude of message signal
fm=100 # frequency of message signal
Ac=1 # amplitude of carrier signal
fc=1000 # fequency of carrier signal
Ka=1 # amplitude sensitivity
τ =3/1000

An envelope detector with capacitor was used to demodulate the Am signal. As shown in fig below.

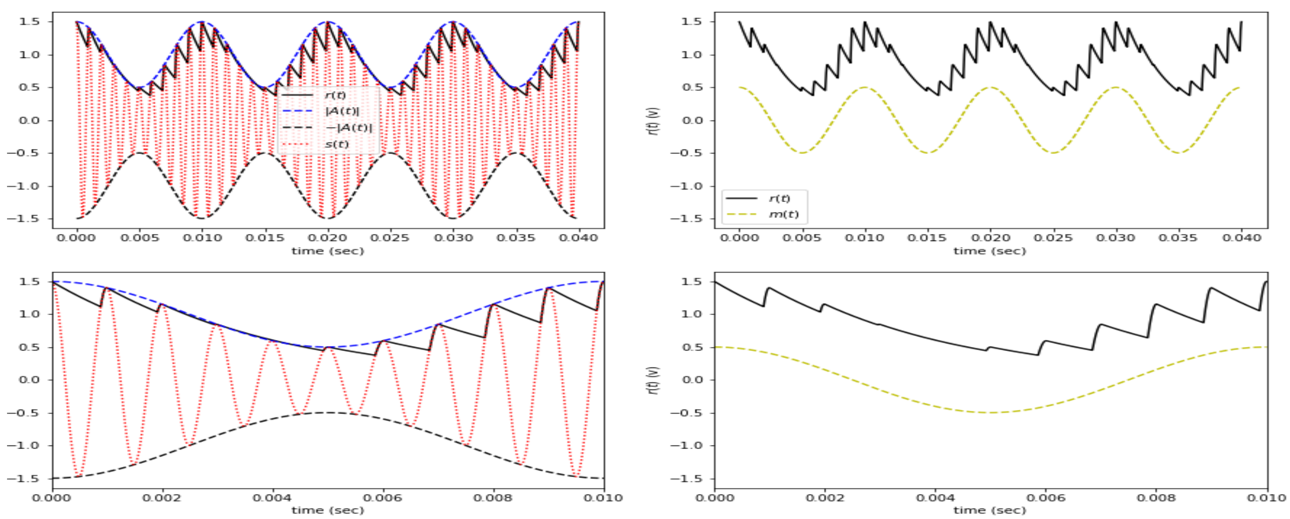


Figure 13: demodulation of Am using envelope detector

- **Note**:

S(t) : massage signal. |A(t)| : positive envelop
-|A(t)| : negative envelop   r(t) : recovered signal

Exercise:

1- a) τ = 10/1000

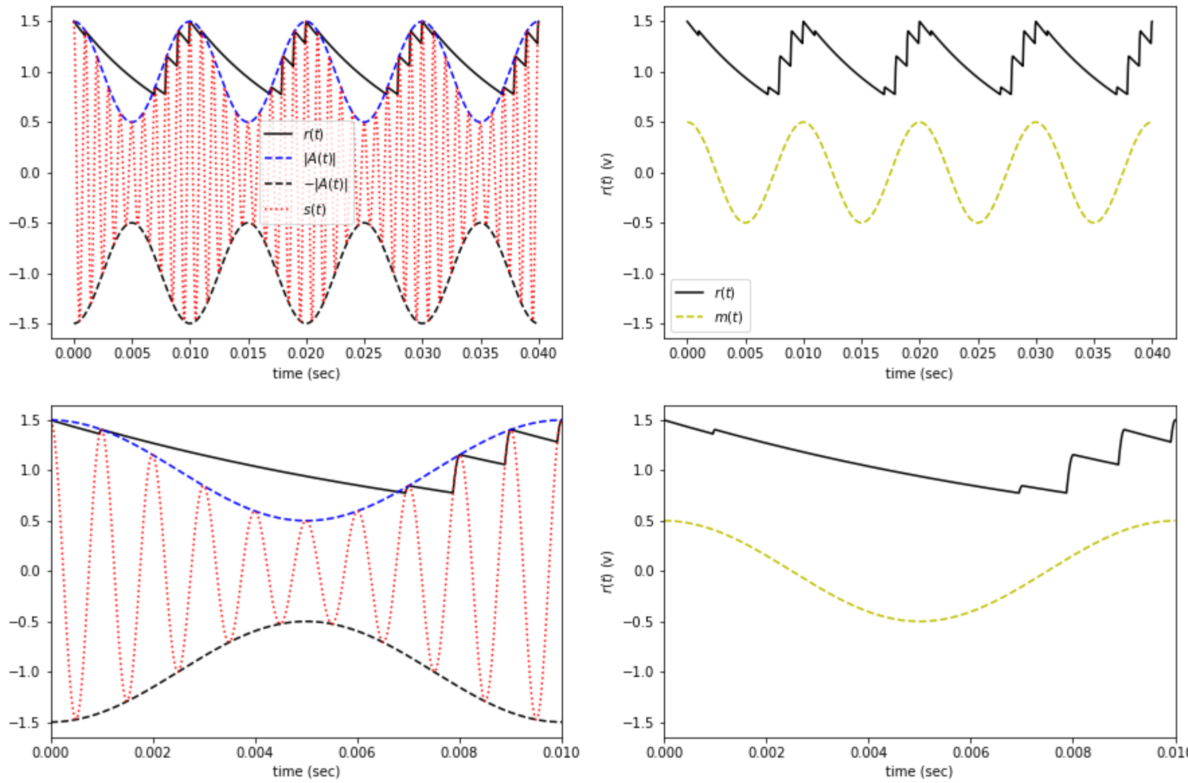


Figure 14: :demodulation of Am using envelope detector with τ =10/1000

- **<u>Note</u>**: when increases τ the capacitor discharging slowly And it is not able to follow the envelop of AM signal .

b) τ = 1/1000

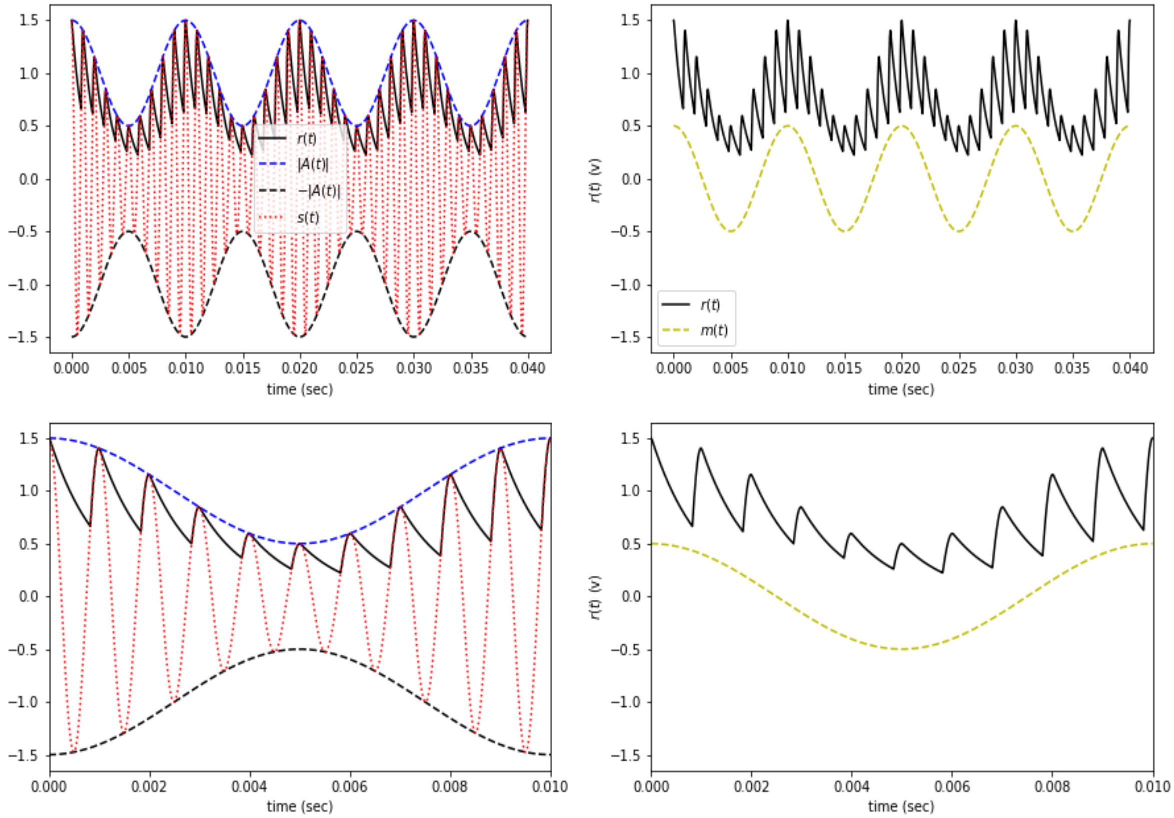


Figure 15:demodulation of Am using envelope detector with τ =1/1000

- **<u>Note</u>**: when decrease the magnitude of τ , discharging time fast But this thing is not good because of the ripple is sharp And it is not able to follow the envelop of AM signal.

c) τ = 4/1000

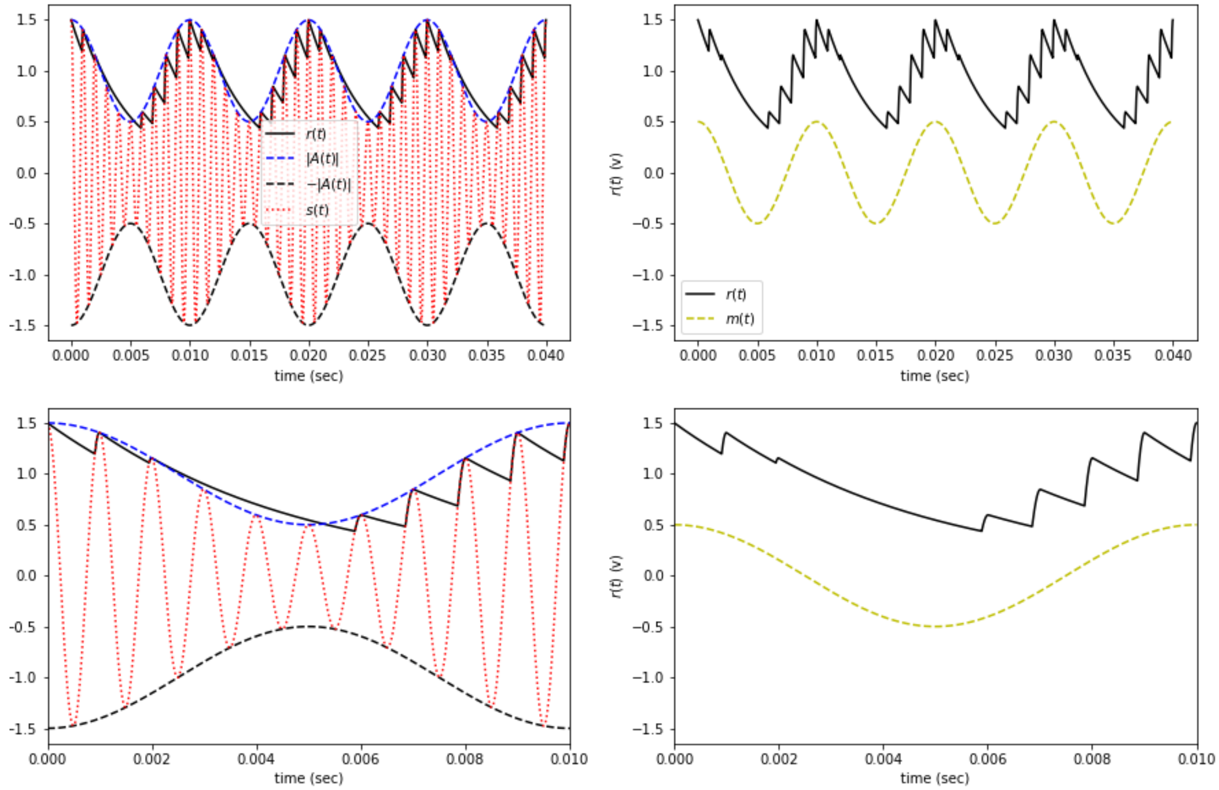


Figure 16:demodulation of Am using envelope detector with τ =4/1000

- **<u>Note</u>**: when chose value of τ between 1/fc and 1/fm this thing good And the ripple able to follow the envelop of AM signal.

2- fc=500 Hz

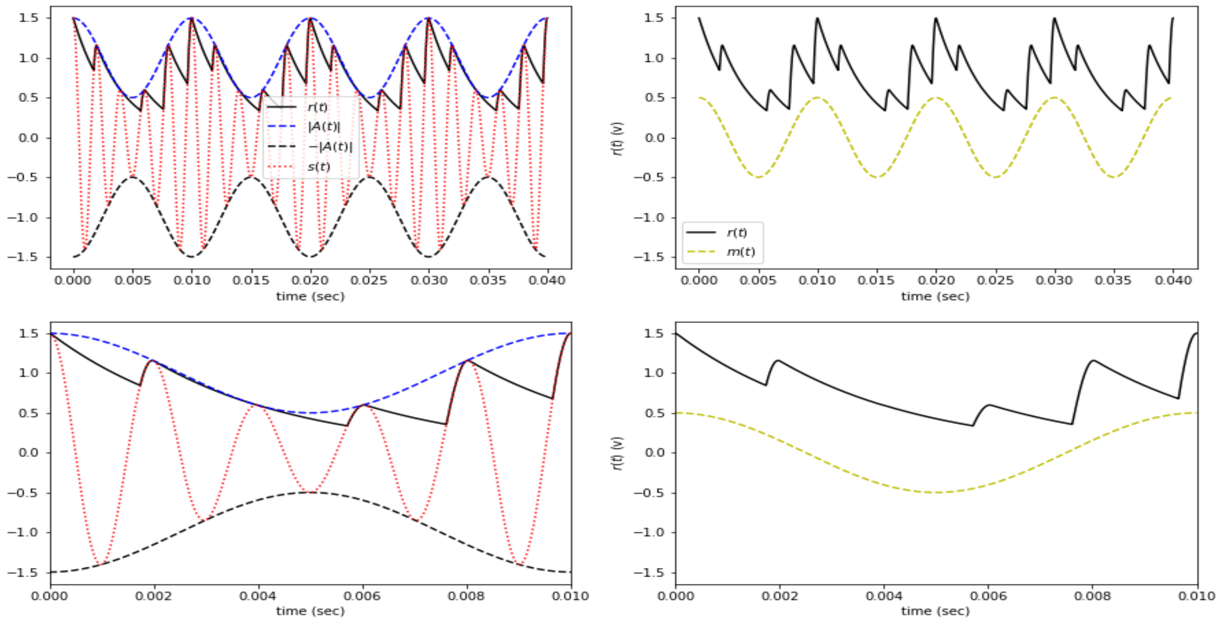


Figure 17: demodulation of Am using envelope detector with fc = 500hz

3- fm=50 Hz

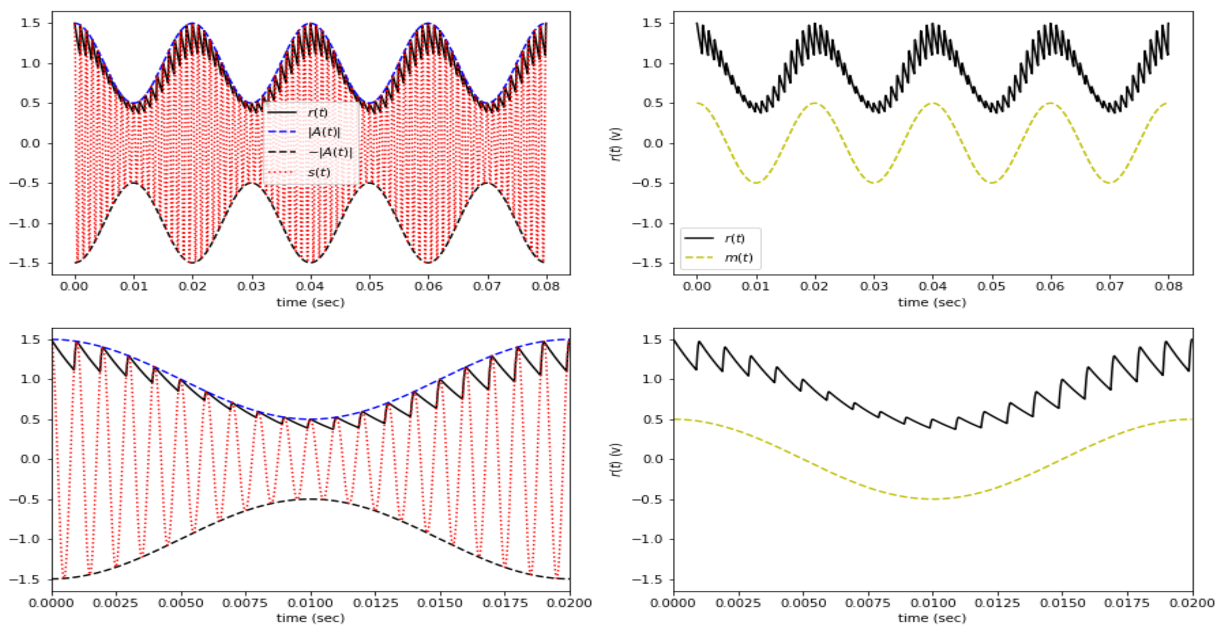


Figure 18: demodulation of Am using envelope detector with fm = 50hz

- **Note**: when fc decreases the ripple increases and when fm decreases the signal becomes moother because we modulated a smaller signal.

4- Ka = 0.5

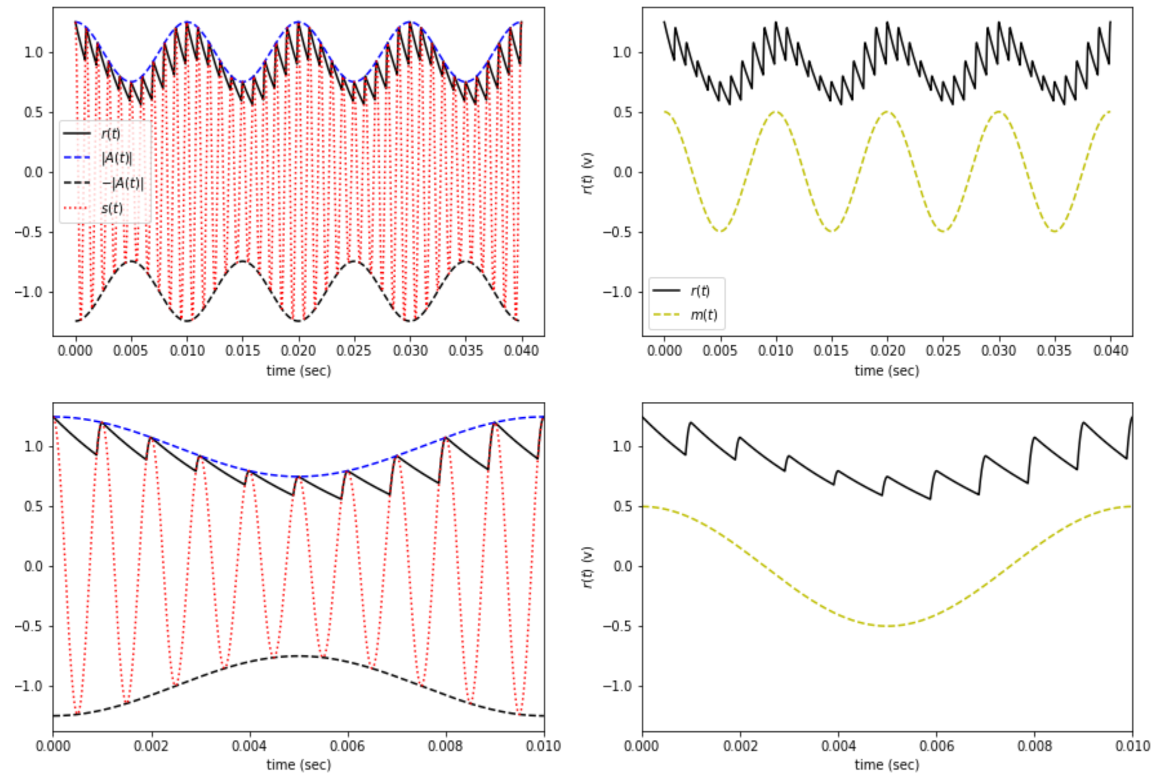


Figure 19: demodulation of Am using envelope detector with Ka= 0.5

- **<u>Note</u>**: The constant Ka is the amplitude sensitivity of the modulator or the transmitter. The percentage of modulation will depend on the absolute value of Ka*m(t). If the absolute value of Ka*m(t) is less or equal to 1 for all t, then the percentage of modulation is less than or equal to 100%. However, if the absolute value of Ka*m(t) is greater than 1 for some t, then the percent of modulation is in excess of 100% or over modulation.