Communication Theory Lab Report

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Communication Theory Lab
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Lab Assignment # 1

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Amplitude and DSB-SC modulation

Abstract

In this experiment, we have tried to understand the concept of Amplitude Modulation (AM) and Double SideBand Suppressed Carrier (DSBSC) in time domain as well as in frequency domain. We analysed them by plotting their graphs in MATLAB. In amplitude modulation, we observed the effect of modulation index on the signals. It was done for both time and frequency domain. We also compared the signals of AM and DSBSC for better understanding.

1 Theory

In carrier modulation, we have a message signal and a carrier signal. Message signal is usually of low frequency and the carrier signal is of very high frequency. The carrier signal acts as an. envelop as it does not carry any information but helps in transmitting the same. carrier signal is given by this formula `C(t) = Ac*cos(2*pi*`f_c`*t)` and here f_c is very high. If you look carefully, it has three components :

1. Amplitude
2. Phase
3. Frequency

In amplitude modulation, amplitude of the carrier signal is changed according to that of the message signal.

Double SideBand Suppressed Carrier (DSBSC) : Consider
`m(t)` as a message signal and
`C(t) = Ac*cos(2*pi*`f_c`*t)` as a carrier signal. Let s(t) be product of m(t) and C(t). So, `s(t) = m(t)*Ac*cos(2*pi*`f_c`*t)`.
The above equations are for time domain.
Now if you consider frequency domain, we will take the Fourier transform of s(t) and let F(s(t)) be the Fourier transform of s(t), then.

F(s(t)) = m(t)$\circledast c(t)$
$=\int_{-\infty}^{\infty} m(\tau) * c(t-\tau) d\tau$
= 1/2 * Ac/2* (M(f-f_c) + M(f+f_c))
(where M(f) = F(m(t)))

Amplitude Modulation (AM) : Consider the terminologies mentioned above, then the amplitude modulated signal r(t) = Ac*cos(2*pi*f_c*t) + s(t)
= Ac*cos(2*pi*f_c*t) + m(t)*cos(2*pi*f_c*t)
= (Ac+m(t))*cos(2*pi*f_c*t)

If you look at the last equation carefully, you will note that for this to be an AM signal, Ac > 0. When Ac = 0, then it becomes the DSBSC signal.

1.1 Block Diagram

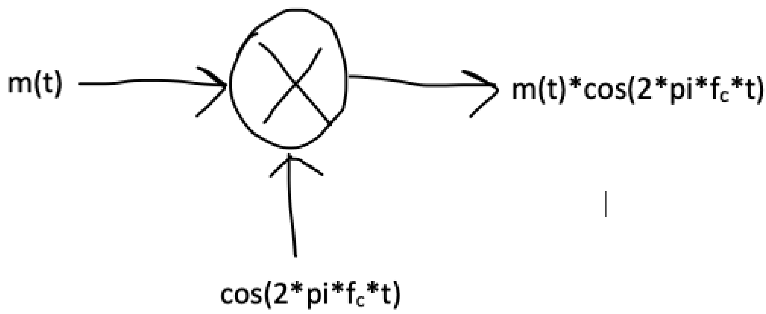

Figure 1: DSBSC block diagram

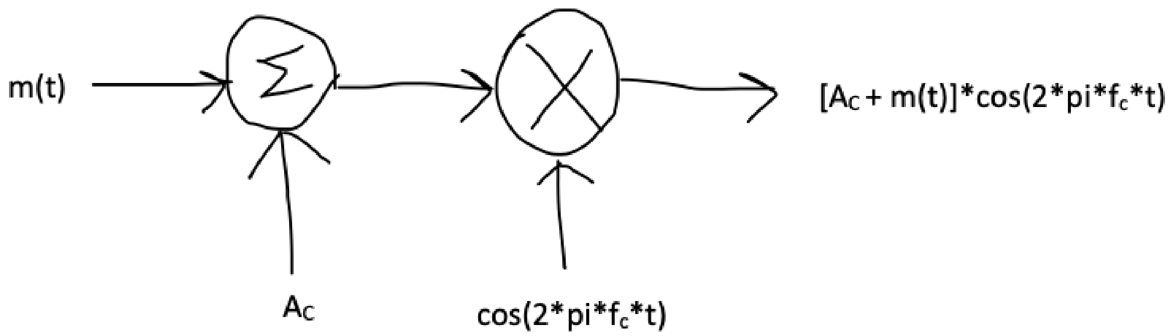

Figure 2: AM block diagram

1.2 Expected Outcome

The figures below are not drawn to scale.

1.2.1 Answer 1

This question was taking inference from what was taught in the lectures. We know that in AM signal, we just add an offset A_c. If this offset is 0, then it becomes DSBSC signal. The question was actually trying to compare A_c and A_m.

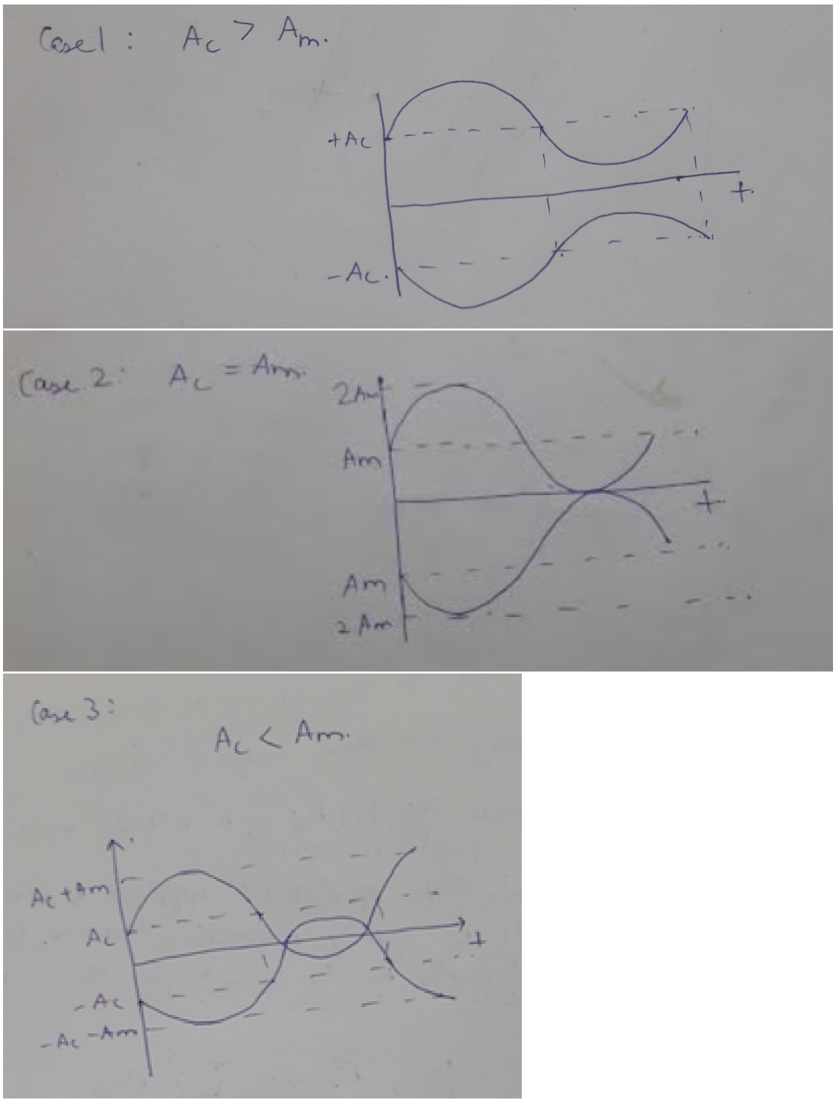

Figure 3: The expected diagrams

1.2.2 Answer 2

This is directly taken from the lecture.

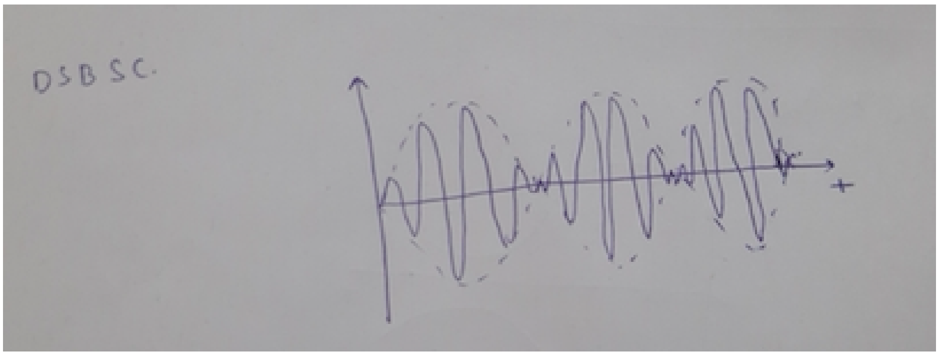

Figure 4: expected DSBSC

1.2.3 Answer 3

This question was taking inference from what was taught in the lectures. In lectures, it was taught that in frequency domain (applying FT on time domain signal) in sinusoidal wave, we get two impulse functions in positive and negative parts. Now, on convolving it with M(f) (FT of m(t)), we should get M(f) on both the sides of y axis. That is what I thought before simulating it on MATLAB.

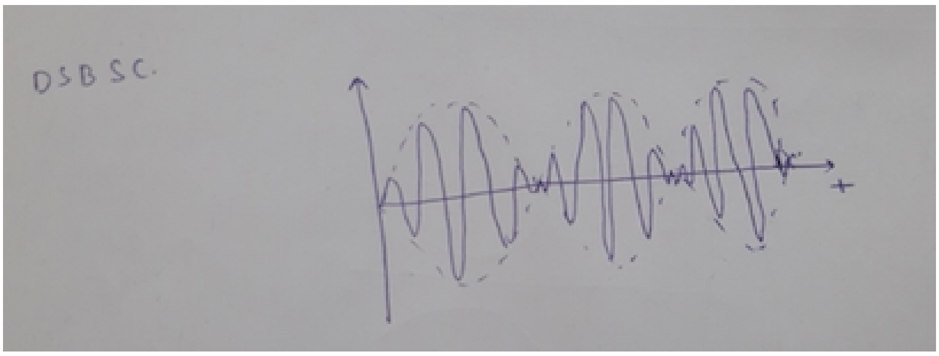

Figure 5: expected FT of AM signal

1.2.4 Answer 4

This is directly taken from the lecture.

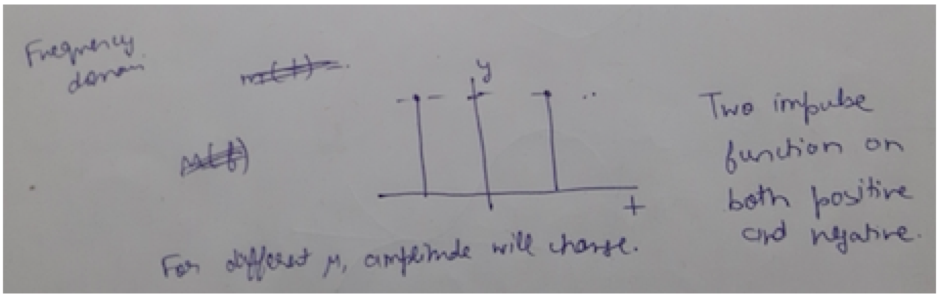

Figure 6: expected FT of DSBSC

1.3 Application

Applications of AM signal :

1. `Data transmission:` AM is used in transmitting data such as in Wifi, cellular telecommunications etc.
2. `Air band radio:` It is used in ground to air communication. Also used in two way communication (ground to air to ground).

Applications of DSBSC signal :

1. `Color transmission:` Currently, DSB is widely used in transmitting color information for televisions.
2. `FM radios:` DSBSC is used in FM radios for the stereo transmission part.

2 Results and Inferences

2.1 Answer 1

1. Ac = Am/mu. So we can see a change in the amplitude of the carrier signal as mu changes. As mu increases, the amplitude decreases.
2. For mu = 0.5, we can see that the signal is not falling to 0. It's positive part is strictly more than zero and its negative part is strictly less than 0. For mu = 1, the signal is touching 0. For mu = 1.5, the signal is having 180 degree phase reversals when the positive part goes below 0 and the negative part goes above 0. This can also be seen from the equation of AM signal : Ac*(1+mu*sin(2*pi*fm*t))*sin(2*pi*fc*t).

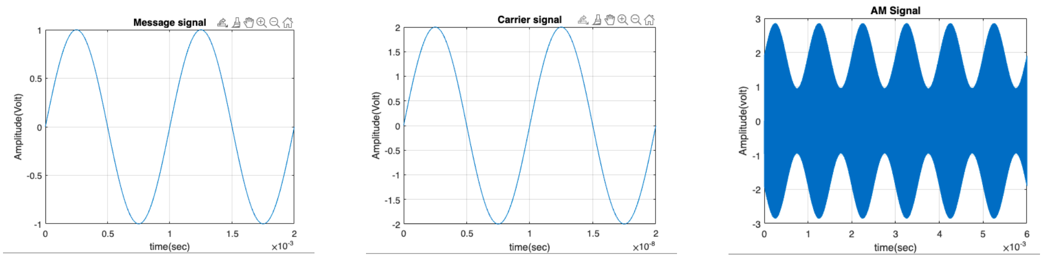

Figure 7: For mu = 0.5

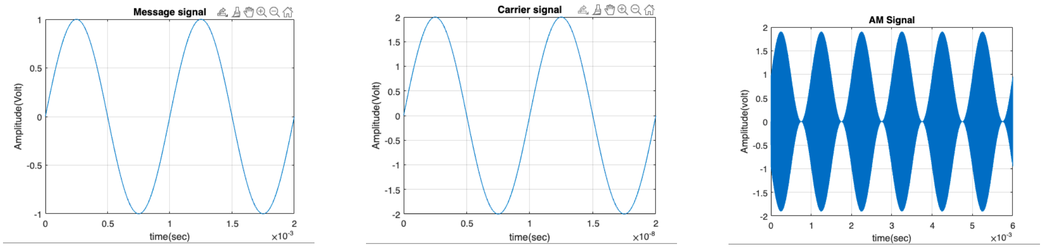

Figure 8: For mu = 1

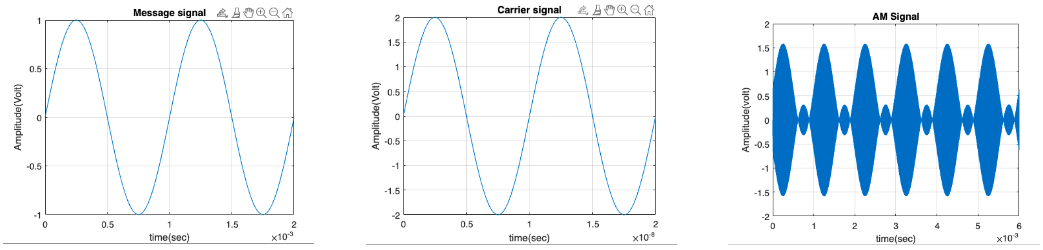

Figure 9: For mu = 1.5

Figure 10: Images for Answer 1

3. In terms of frequency, it is similar for both Amplitude modulated and the carrier signal.

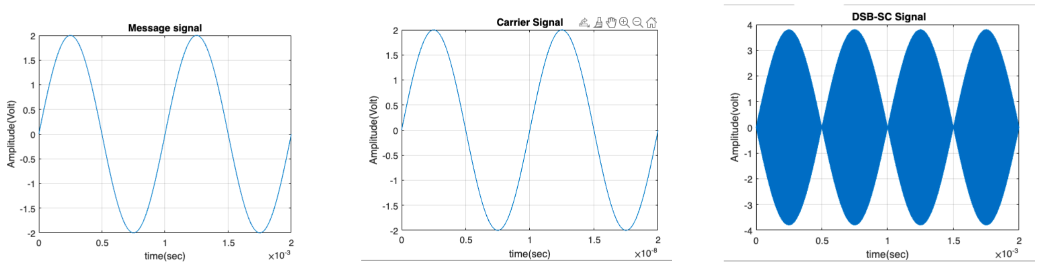

Figure 11: Images for Answer 2

2.2 Answer 2

The figure above shows the DSB-SC signal. We can see that the carrier signal is suppressed and the information is being transmitted through the modulated signal only.
Inferences are :

1. The amplitude of the DSBSC signal is equal to product of message signal and the carrier signal.

2. The maximum frequency of the DSBSC signal is $f_c + f_m$ and the minimum is $f_c - f_m$.

The DSB-SC equation is written as follows:

DSB-SC = m(t)*(Ac*sin(2*pi*fc*t) ...equation 1
= (2*sin(2*pi*1000*t))*(2*sin(2*pi*108 *t)) ...putting the values as per question
Putting the equation of m(t), DSB-SC = 4*sin(2*pi*1000*t)*sin(2*pi*108 *t).

Similarly, we have the AM signal which is,
AM = Ac*(1+mu*sin(2*pi*fm*t))*sin(2*pi*fc*t) ...equation 2
Since mp=Ac=2V, the maximum and minimum amplitude is varying from +4V to -4V. No, This case is not the same as in part1(a). The carrier wave is suppressed in case of DSB-SC, that means it is not getting transmitted along with the modulated signal. Part1(a) is amplitude modulation where we transmit carrier waves along with the modulated signal.

2.3 Answer 3

1. Ac = Am/mu. So we can see a change in the amplitude of the FT of carrier signal as mu changes.

2. This is the AM signal equation in time domain :
   Am =Ac*(1+mu*sin(2*pi*fm*t))*sin(2*pi*fc*t)
   Here we can see there is a multiplication (for the modulated signal part), so in the frequency domain, it will get changed to the convolution operator. Both carrier and message signal is sine, whose Fourier transform (FT) is shown above (1st and 2nd figure). For the third one in each row, it is the sum of convolution of these two and the FT of the carrier signal.

3. We can observe impulses in the transform because the modulating waves are sinusoidal.

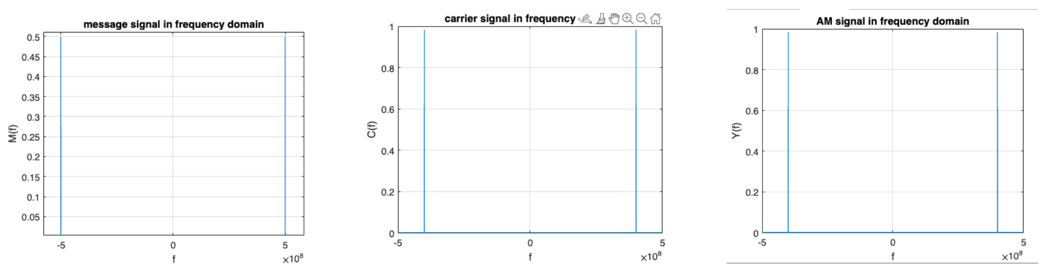

Figure 12: For mu = 0.5

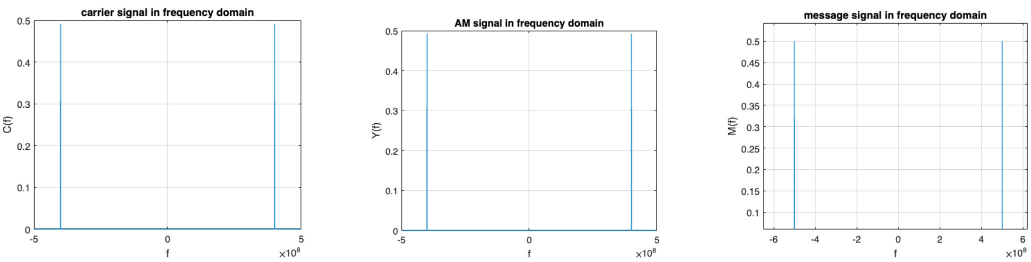

Figure 13: For mu = 1

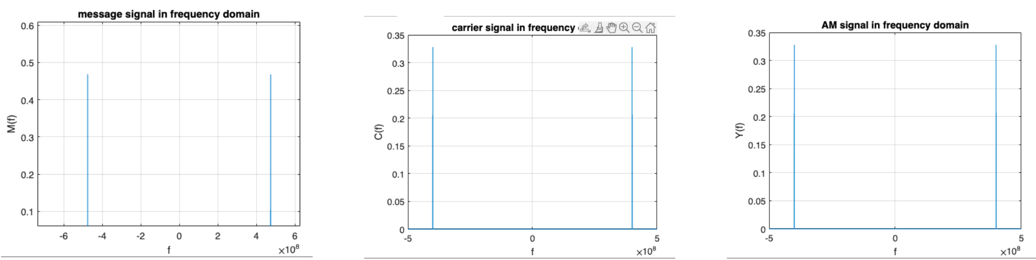

Figure 14: For mu = 1.5

Figure 15: Images for Answer 3

2.4 Answer 4

Inferences are:

1. We can see that the amplitude in the plot for carrier signal is 2V. This is because of the transformation from its time domain to frequency domain. Same is the case with the message signal.

2. Frequency of the modulating signal is 1K Hz and that of carrier is 100MHz.

DSB-SC = m(t)*(Ac*sin(2*pi*fc*t)
= (2*sin(2*pi*1000*t))*(4*sin(2*pi*108 *t))
= 8*sin(2*pi*1000*t)*sin(2*pi*108 *t)

Here we can see that there is a multiplication between carrier and message signal in the time domain. Therefore, in the frequency domain, it will be the convolution operation of individual FT of signals.
No, this scenario is not the same as for part1(c). There is a difference in the magnitude of impulse signal in frequency domains. This is because in AM, we have addition as well as convolution in the frequency domain. Here we only have convolution.

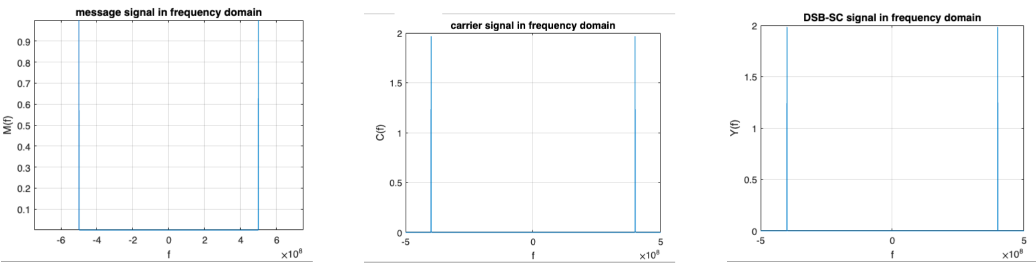

Figure 16: Images for Answer 4

Appendix

A Matlab Commands

Table 1: Matlab commands used in this lab.

Matlab Command	**Function**
`plot(`x, y`)`	plots values of the simulation series y along the y-axis, with values of the simulation series x along the x-axis.
`figure()`	creates a new figure in MATLAB.
`title(x)`	adds a title x to the plot
`xlabel(x)`	adds a horizontal label x (along x axis) to the plot
`ylabel(x)`	adds a vertical label x (along y axis) to the plot
`grid on`	adds a grid to the plot.
`clc`	clears everything from the matlab command line window.
`linspace(x1,x2,p)`	generates p equally distant points between x1 and x2.

B Matlab Code

Matlab codes for each part.

B.1 Q1(a)

```
clc;
% message signal
mp = 1;
fm = 1000;
% tm = 0.001
tm = 1/fm;
% time for simulation
```

```
t = (0:tm/1000000:2*tm);
mt = mp*sin(2*pi*fm*t);
% figure plot 1
figure();
plot(t,mt);
title("Message signal");
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
grid on;
% Carrier signal
% mu can be any value out of 0.5,1,1.5.
% Change the value accordingly
mu = 1.5;
Ac = mp/mu;
fc = 100*1000000;
tc = 1/fc;
t = (0:tm/100000000000:2*tc);
mc=Ac*sin(2*pi*fc*t);
% figure plot 2
figure();
plot(t,mc);
title("Carrier signal");
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
grid on;
% Am signal
t = (0:tm/1000000:6*tm);
phi=Ac*(1+mu*sin(2*pi*fm*t)).*sin(2*pi*fc*t);
figure();
plot(t,phi);
title("AM Signal");
xlabel("time(sec)");
ylabel("Amplitude(volt)");
grid on;
```

B.2 Q1(b)

```
clc;

% message signal
```

```
mp =2;
fm = 1000;
tm = 1/fm;
t = 0:tm/1000000:2*tm;
ym = mp*sin(2*pi*fm*t);
figure();
plot(t,ym);
grid on;
title("Message signal");
xlabel("time(sec)");
ylabel("Amplitude(Volt)");

% Carrier signal
Ac=2;
fc=100*1000000;
tc=1/fc;
t = (0:tm/100000000000:2*tc);
yc=Ac*sin(2*pi*fc*t);
figure();
plot(t,yc);
grid on;
title("Carrier Signal");
xlabel("time(sec)");
ylabel("Amplitude(Volt)");

% DSB-SC
t = (0:tm/1000000:2*tm);
y=Ac*(mp*sin(2*pi*fm*t)).*sin(2*pi*fc*t);
figure();
plot(t,y);
title(" DSB-SC Signal");
xlabel("time(sec)");
ylabel("Amplitude(volt)");
grid on;
```

B.3 Q1(c)

```
clc;

% setting time period
```

```
t=(0:1/10^9:0.006);
N= length(t);
f=linspace(-10^9/2,10^9/2,N);

% modulation index
% Please change the value of u here
u= 1;
Am=1;
Ac=Am/u;
fm=1000;
fc=10^8;

% message signal
m_t = Am*sin(2*pi*fm*t);
M_F=abs(fft(m_t,N));
figure();
plot(f,(M_F/N));
title("message signal in frequency domain");
xlabel("f");
ylabel("M(f)");
grid on;

%carrier signal
c_t = Ac*sin(2*pi*fc*t);
C_F=abs(fft(c_t,N));
figure();
plot(f,(C_F/N));
title("carrier signal in frequency domain");
xlabel("f");
ylabel("C(f)");
grid on;

%AM Signal
y_t=Ac*(1+u*sin(2*pi*fm*t)).*sin(2*pi*fc*t);
y_F=abs(fft(y_t,N));
figure();
plot(f,(y_F/N));
title("AM signal in frequency domain");
xlabel("f");
ylabel("Y(f)");
grid on;
```

B.4 Q1(d)

```
%getting time period
Am=2;
Ac=4;
fm=1000;
fc=10^8;
t=(0:1/10^9:0.006);
N=length(t);
f=linspace(-10^9/2,10^9/2,N);

%message signal
m_t = Am*sin(2*pi*fm*t);
M_F=abs(fft(m_t,N));
figure();
plot(f,M_F/N);
title("message signal in frequency domain");
xlabel("f");
ylabel("M(f)");
grid on;

%carrier signal
c_t = Ac*sin(2*pi*fc*t);
C_F=abs(fft(c_t,N));
figure();
plot(f,(C_F/N));
title("carrier signal in frequency domain");
xlabel("f");
ylabel("C(f)");
grid on;

%DBS-SC Signal
mp = 2;
y_t=Ac*(mp*sin(2*pi*fm*t)).*sin(2*pi*fc*t);
y_F=abs(fft(y_t,N));
figure();
plot(f,(y_F/N));
title("DSB-SC signal in frequency domain");
xlabel("f");
ylabel("Y(f)");
grid on;
```

References

[1] IIT Mandi lectures on EE304 offered by Dr Adarsh https://cloud.iitmandi.ac.in/d/4bb3a5f304334160ab67/

[2] Tutorial Point lectures on DSBSC signal https://www.tutorialspoint.com/analog_communication/analog_communication_dsbsc_modulation.htm

[3] Research overview by Comprehensive Nanoscience and Nanotechnology https://www.sciencedirect.com/topics/engineering/amplitude-modulation