Expt. No. 8 AdmNo: U19CS048 Date 21/10/2020 Page Nos: 123-136

Experiment No : 08

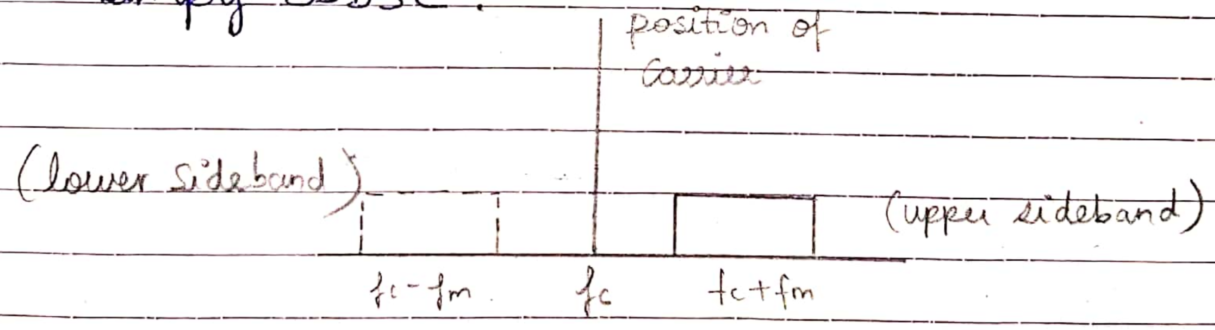
SINGLE SIDE BAND (SSB-SC) MODULATION SCHEME

Objective: Write and simulate a program for single side-band modulation scheme. Draw the message / Carrier waveforms and resultant modulated signal in the time domain and frequency domain. Show the input/output waveforms using Matlab code / simulink in virtual mode.

Software: Matlab

Theory:

The process of suppressing one of the sidebands along with the carrier and transmitting a single sideband is called as single sideband suppressed carrier system or simply SSBSC.



Here, the carrier and the lower sideband are suppressed. Hence, the upper sideband is used for transmission. Similarly, we can suppress the carrier and the upper sideband with the transmission of the lower sideband. This is because in SSBSC, both upper side band and lower side band have the same information.

Mathematical Expressions:

Let Modulating signal $\Rightarrow m(t) = A_m \cos 2\pi f_m t$

Let Carrier Signal $\Rightarrow c(t) = A_c \cos 2\pi f_c t$

SSBSC wave, $s(t) = m(t)\, c(t)$

$s(t) = \frac{A_m A_c}{2} \cos[2\pi (f_m + f_c) t]$ for upper sideband

$s(t) = \frac{A_m A_c}{2} \cos[2\pi (f_c - f_m) t]$ for lower sideband

Bandwidth of SSBSC:

In DSBSC modulated wave, the wave contains two sidebands and its bandwidth is $2f_m$. Since SSBSC modulated wave contains only one side band, its bandwidth is half of the bandwidth of the DSBSC modulated wave.

$\therefore$ Bandwidth of SSBSC wave $= f_m$

Therefore, the bandwidth required is same as the required for the modulating signal.

Power Calculations:

As SSBSC wave equation, $s(t) = \frac{A_m A_c}{2} \cos[2\pi (f_c + f_m) t$ (for USB)

$s(t) = \frac{A_m A_c}{2} \cos(2\pi [f_c - f_m] t)$ (for LSB)

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Power of SSBSC is equal to the power of any one side-band frequency components :

$$P = P_{USB} = P_{LSB}$$

As, $P = \frac{(V_{rms})^2}{R} = \frac{(V_m/\sqrt{2})^2}{R}$

$$P_{USB} = \frac{(A_m A_c / 2\sqrt{2})^2}{R} = \frac{A_m^2 A_c^2}{8R}$$

$$P_{LSB} = \frac{A_m^2 A_c^2}{8R}$$

$$\therefore \boxed{P_{SSBSC} = \frac{A_m^2 A_c^2}{8R}}$$

Therefore, the power required is ~~the~~ less than that required for DSBSC wave.

Generation of SSBSC

There are two methods for the generation of SSBSC :

1) Frequency discrimination Method
2) Hilbert transform method or phase discrimination method.

1) FREQUENCY DISCRIMINATION METHOD :-

In this method, first we will generate DSBSC wave with the help of the product modulator. Then apply this DSBSC wave as an input of band pass filter. The band pass filter produces output, which is SSBSC wave.

Select the frequency range of band pass filter as the spectrum of desired SSBSC wave. This means the band pass filter can be tuned to either USB or LSB frequencies to get respective SSBSC wave having USB or LSB.

2) PHASE DISCRIMINATION METHOD OR HILBERT TRANSFORM METHOD :-

The block diagram consists of two product product modulators, two 90° phase shifters.

The modulating signal $A_m \cos(2\pi f_m t)$ and carrier signal $A_c \cos(2\pi f_c t)$ are applied to product modulator. The output ⇒

$$s_1(t) = A_m A_c \cos(2\pi f_m t) \cos(2\pi f_c t)$$

$$s_1(t) = \frac{A_m A_c}{2} \{ \cos(2\pi (f_c + f_m) t) + \cos[2\pi (f_c - f_m) t] \}$$

The output of modulating and carrier signals passed through -90° phase shifter and then product modulator:

$$s_2(t) = A_m A_c \cos(2\pi f_m t - 90^\circ) \cos(2\pi f_c t - 90^\circ)$$

$$s_2(t) = \frac{A_m A_c}{2} [\cos(2\pi (f_c - f_m) t) - \cos[2\pi (f_c + f_m) t]]$$

Adding $s_1(t)$ and $s_2(t)$,

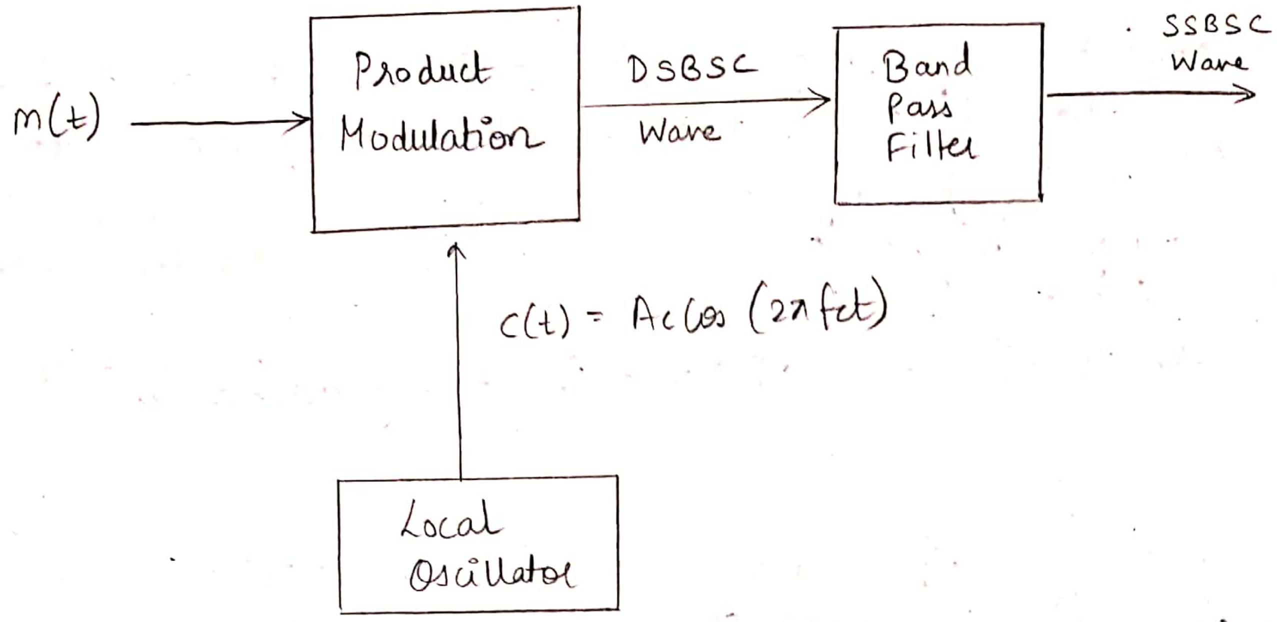
$$s(t) = A_m A_c \cos[2\pi (f_c - f_m) t] \Rightarrow \text{Lower sideband}$$

Subtract $s_2(t)$ from $s_1(t)$,

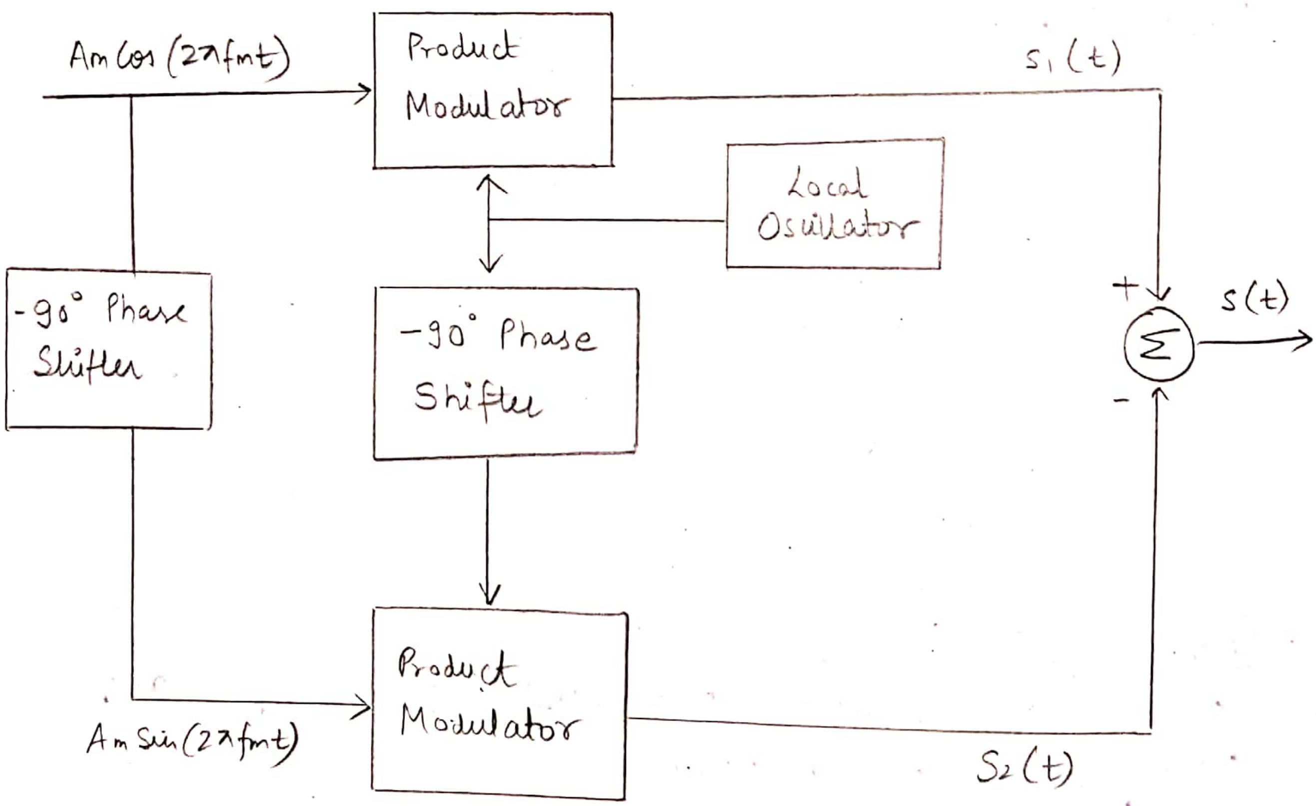
$$s(t) = A_m A_c \cos[2\pi (f_c + f_m) t] \Rightarrow \text{Upper Sideband}$$

Therefore, choosing correct polarities of input of summer block will get SSBSC having upper sideband or lower sideband.

Frequency Deleminiation Method :→



Phase Discrimination Method :→



MATLAB Code:

```
clc;
clear all;
close all;
am=1;        % amplitude of modulating signal
ac=1;        % amplitude of carrier signal
fm=500;      % modulating signal frequency
fc=5000;     % carrier frequency
fs=100000;   % Sampling frequency
ts=1/fs;     % Sampling Interval
N=10000;     % No of samples
t=(-N/2:1:(N/2-1))*ts;     % time interval
m=am*cos(2*pi*fm*t);       % modulating signal
mh=am*sin(2*pi*fm*t);      % hilbert transformation message signal
c=ac*cos(2*pi*fc*t);       % carrier signal
ch=ac*sin(2*pi*fc*t);      % hilbert transformation carrier signal
st=m.*c-mh.*ch;            % SSBSC signal

% time domain of all signals
subplot(3,2,1);
plot(t,m,'red','linewidth',1.5);
axis([0 0.005 -2.5 2.5]);
xlabel('time');
ylabel('amplitude');
title('modulating signal');
grid on;
```

```
subplot (3,2,3);
plot (t, c, 'black', 'linewidth', 1.5);
axis ([0 0.005 -2.5 2.5]);
xlabel ('time');
ylabel('amplitude');
title('carrier signal');
grid on;

subplot (3, 2, 5);
plot [t, st, 'blue', 'linewidth', 1.5);
axis ([0 0.005 -2.5 2.5]);
xlabel ('time');
ylabel ('amplitude');
title ('modulated signal');
grid on;

% spectrum of all signals
f = (-N/2 : 1 : (N/2 -1)) * fs/N ;
M = abs ((2/N) * fftshift (fft(m)));
C = abs ((2/N) * fftshift (fft (c)));
SF = abs ((2/N) * fftshift ( fft(st)));
subplot (3,2,2);
plot (f, M/max(M), 'red', 'linewidth', 1.5 );
axis( [-2 *fc 2* fc -0.1 1.1]) ;
Xlabel ('frequency');
ylabel ('amplitude');
title ('modulating signal');
grid on;
```

```
subplot (3,2,4);
plot (f, C/max(C), 'black', 'linewidth', 1.5);
axis([-2*fc 2*fc -0.1 1.1]);
xlabel ('frequency');
ylabel('amplitude');
title ('Carrier signal');
grid on;

subplot (3,2,6);
plot (f, SF/max (SF), 'blue', 'linewidth', 15);
axis ([-2*fc 2*fc -0.1 1.1]);
xlabel ('frequency');
ylabel ('amplitude');
title ('modulating signal');
grid on;
```

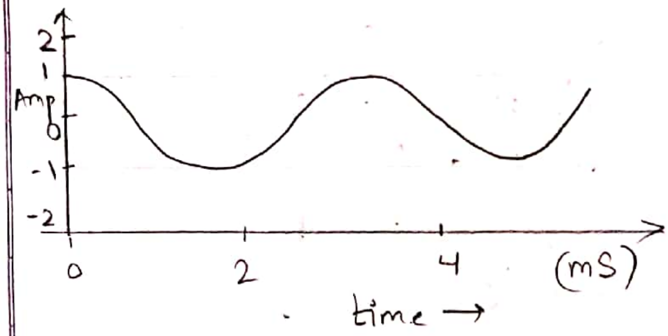
Observations:

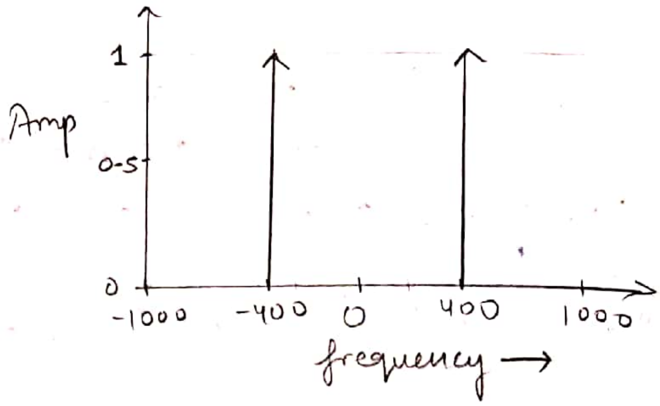
Sampling freq = 100KHZ   No. of samples = 10000
Amplitude of Carrier = 1   Amplitude of modulating Signal = 1

Modulating freq (fm)	Carrier freq (fc)	SSBSC freq:
400	2000	2400
200	3000	3200
300	4000	4300
500	2000	2500
500	5000	5500

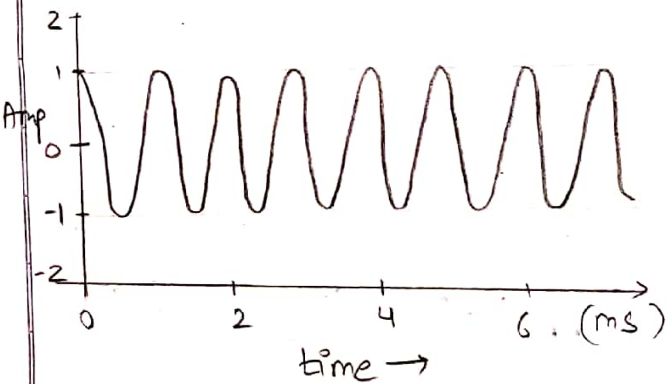
1) $f_m = 400$, $f_c = 2000$

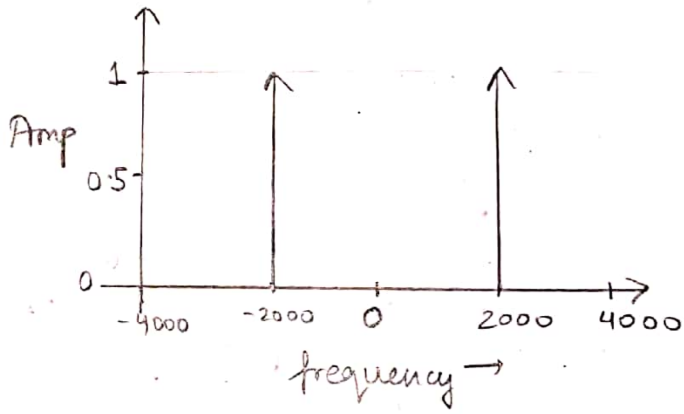
Modulating Signal



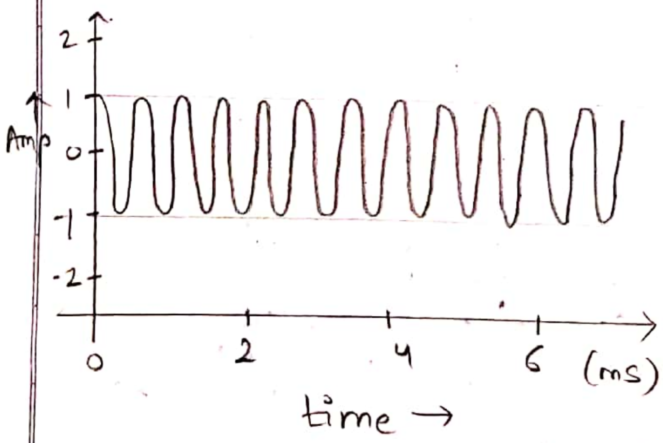


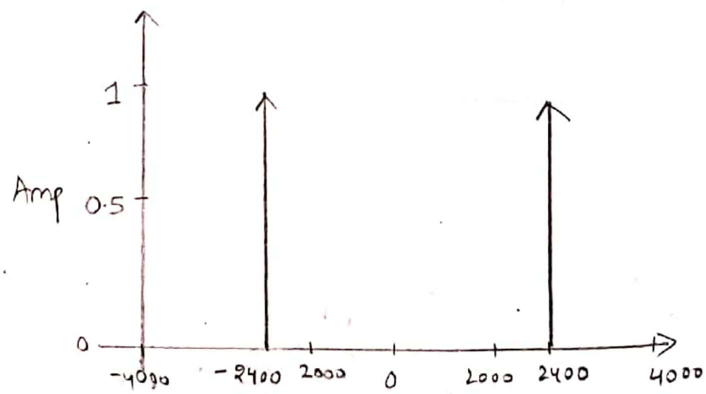
Carrier Signal





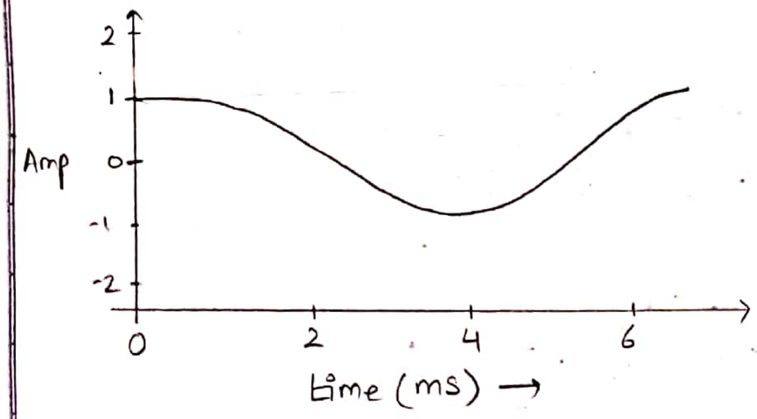
Modulated Signal

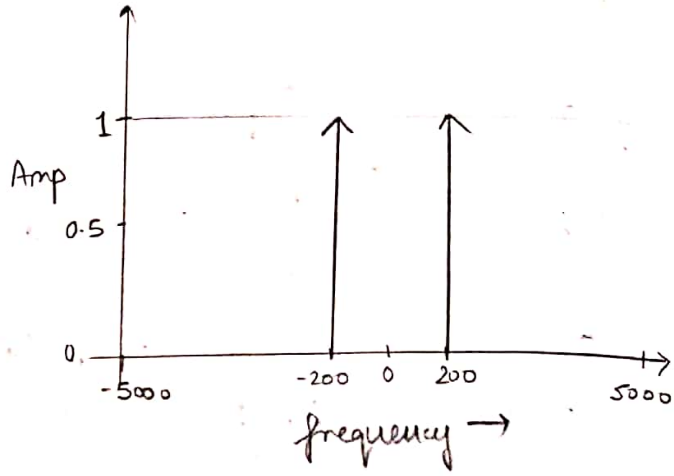




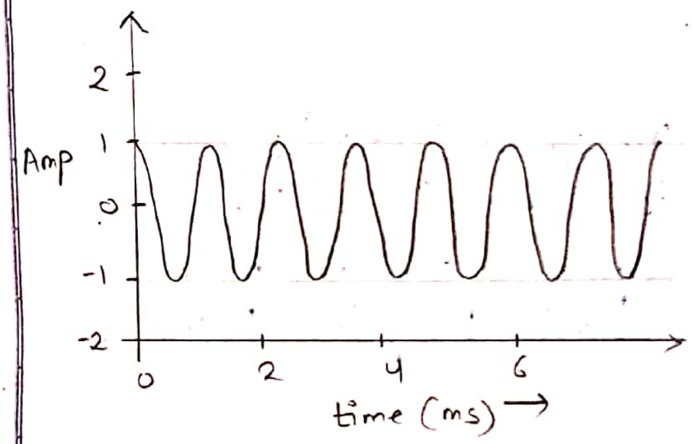
2) $f_m = 200$, $f_c = 3000$

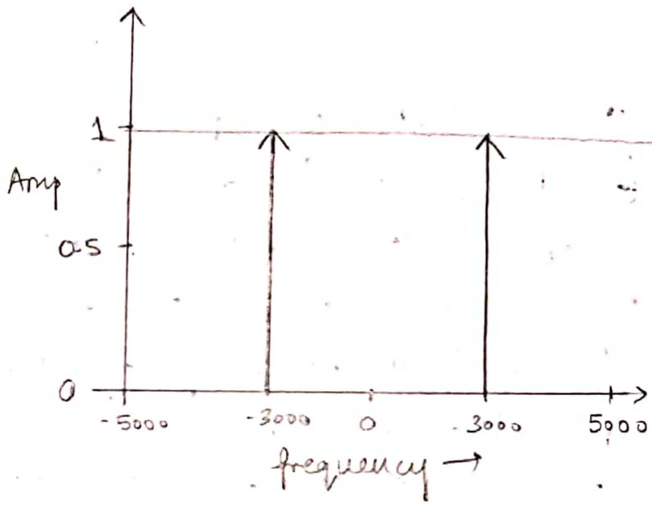
Modulating signal



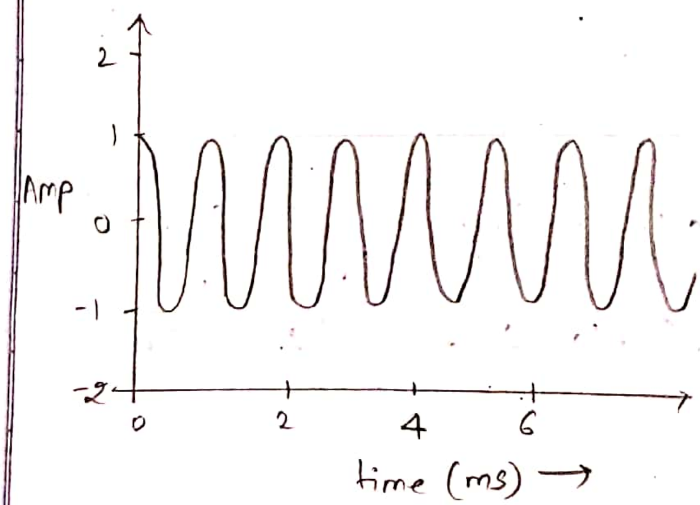


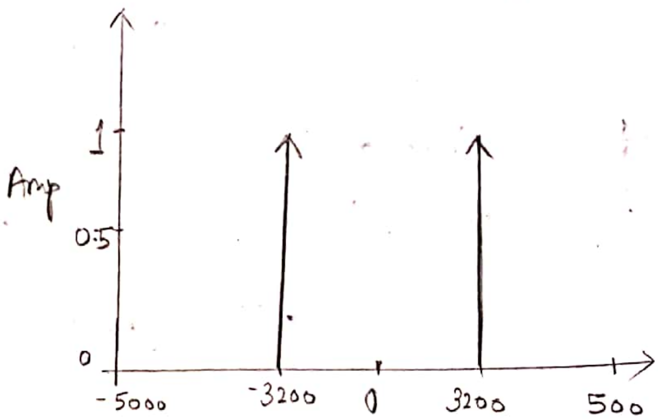
Carrier Signal





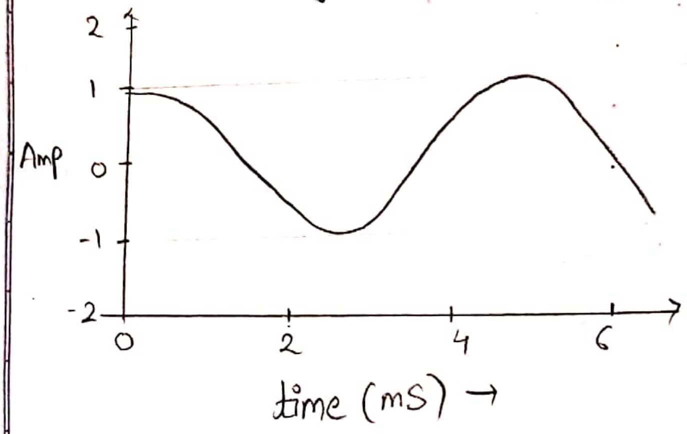
Modulated Signal

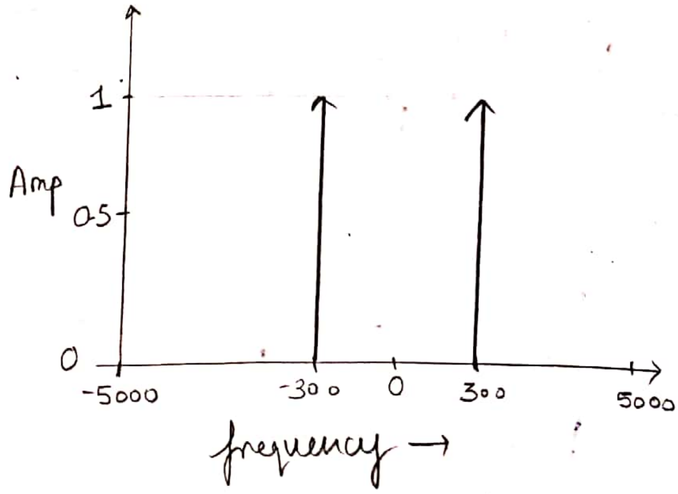




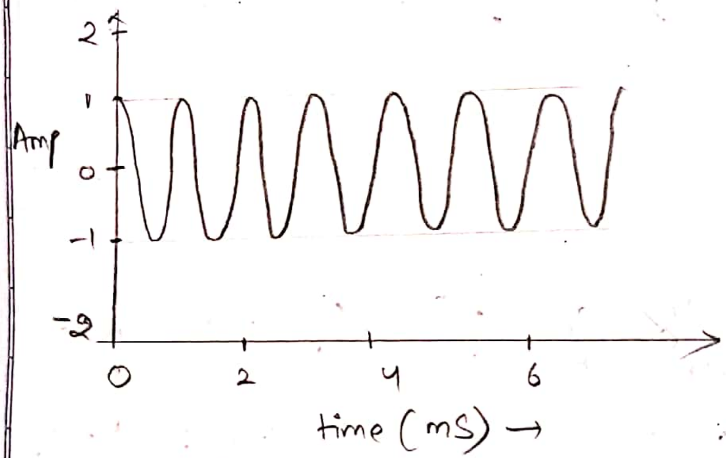
3) $f_m = 300$, $f_c = 4000$

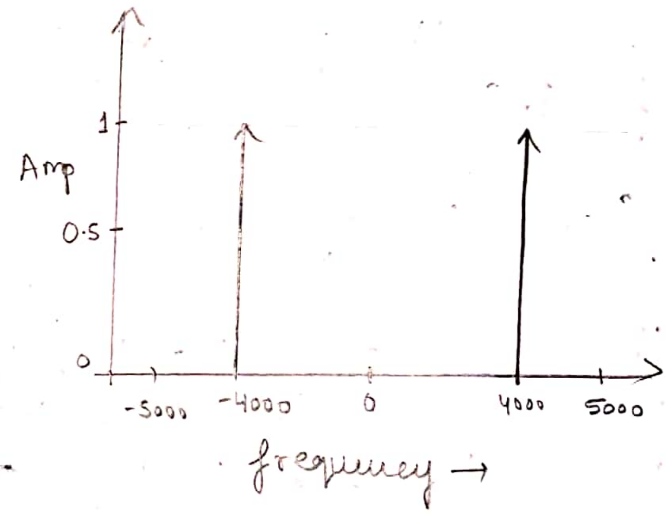
Modulating Signal



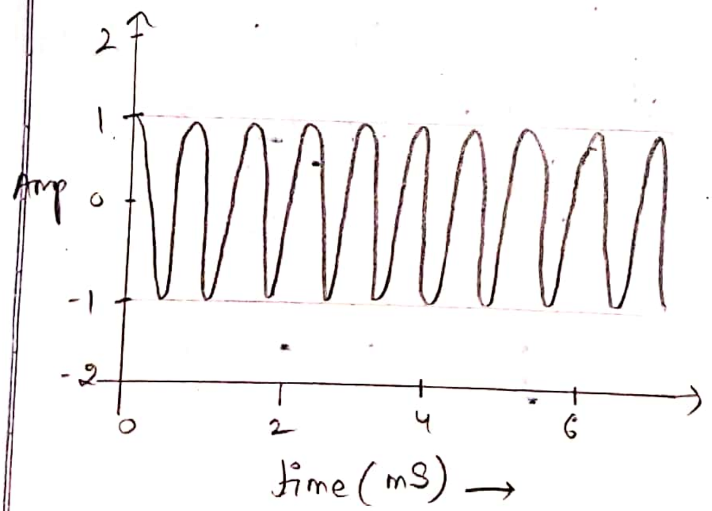


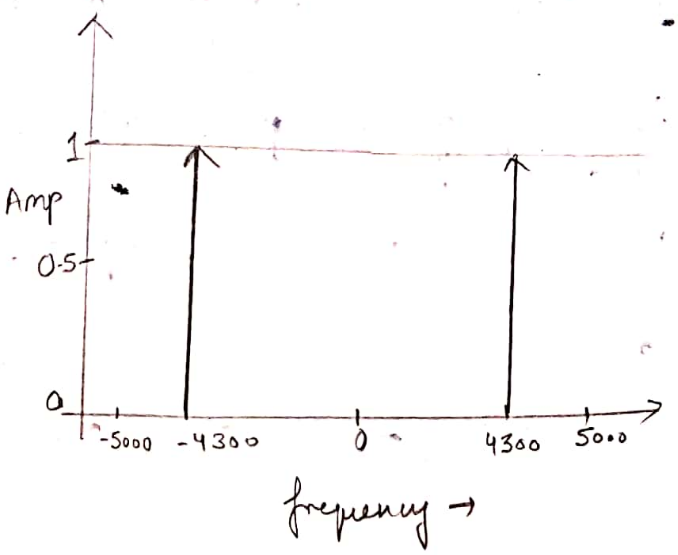
Carrier Signal





Modulated Signal





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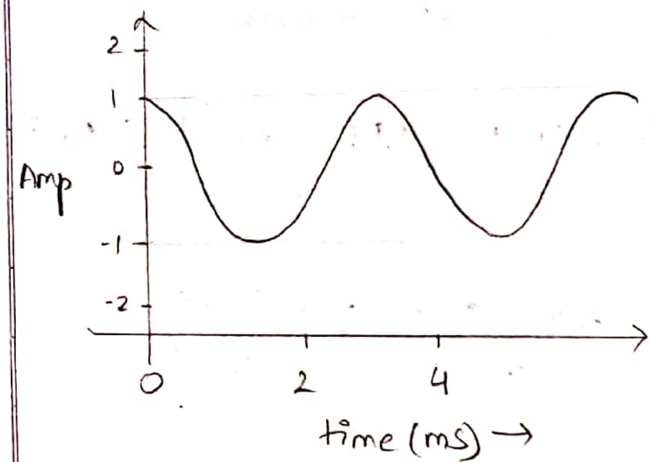
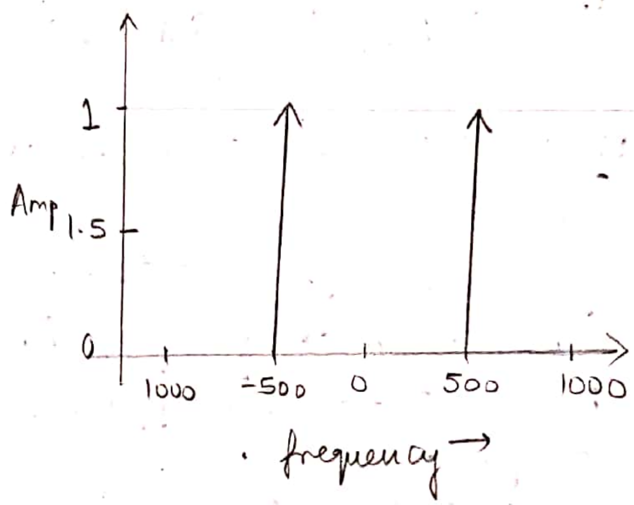
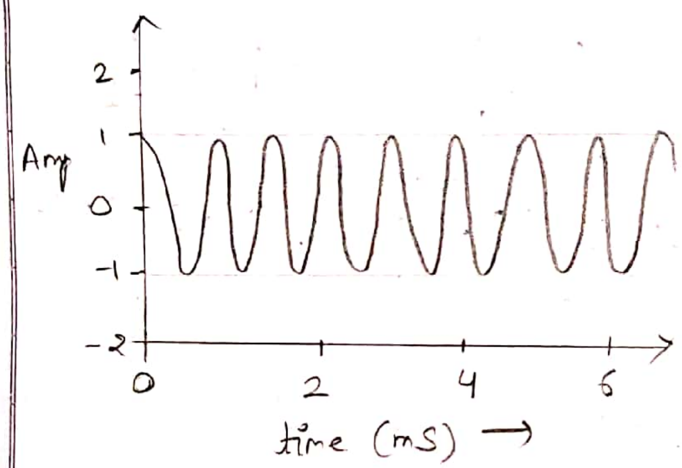
4) $f_m = 500$, $f_c = 2000$

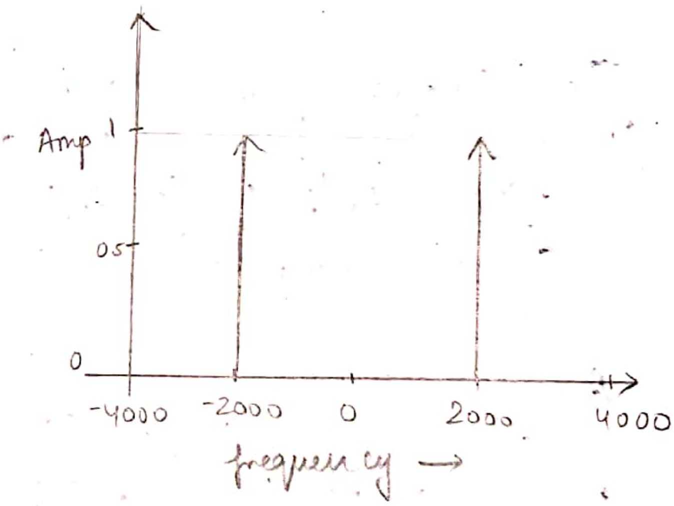
Modulating Signal



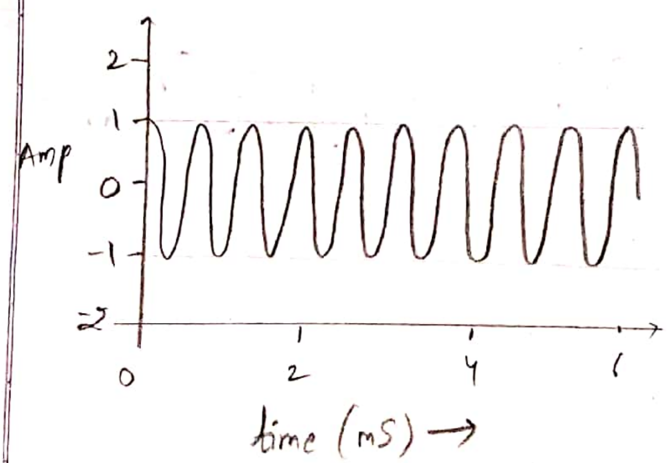


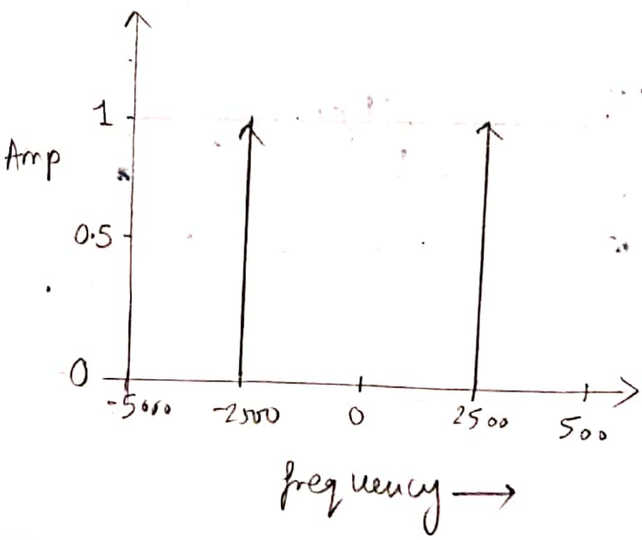
Carrier Signal





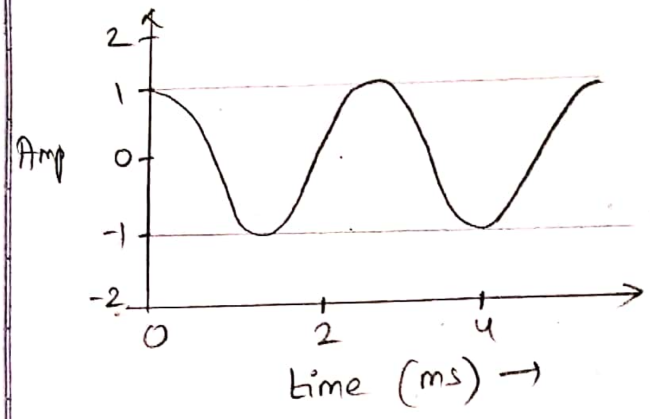
Modulated Signal

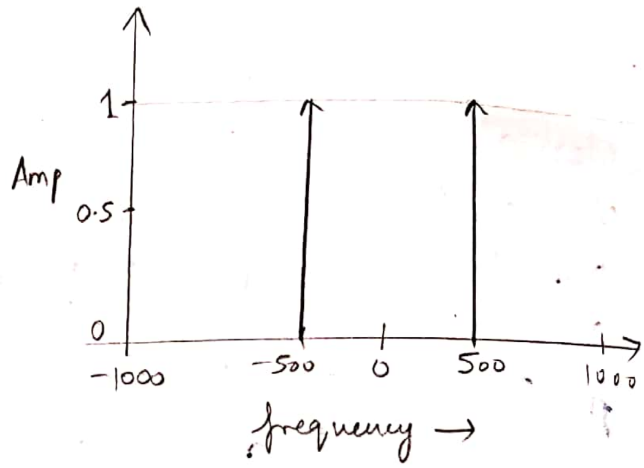




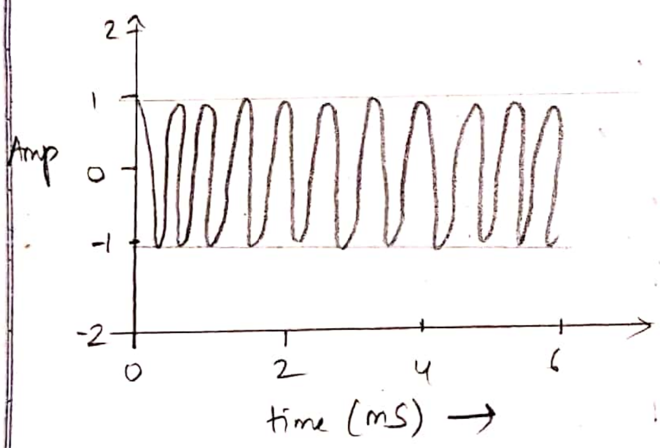
5) $f_m = 500,\ f_c = 5000$

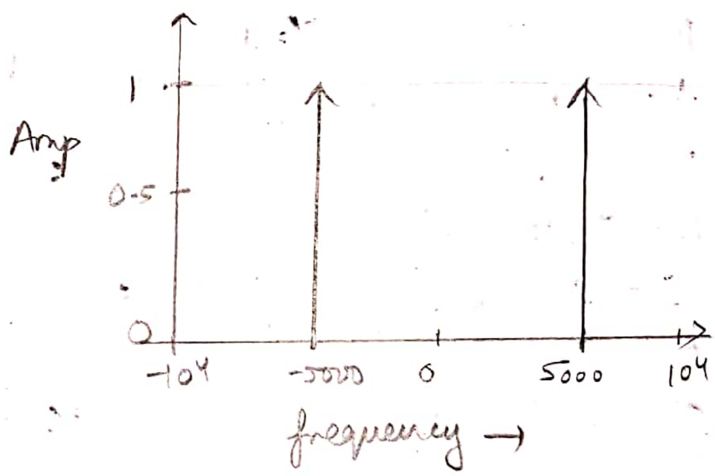
Modulating Signal



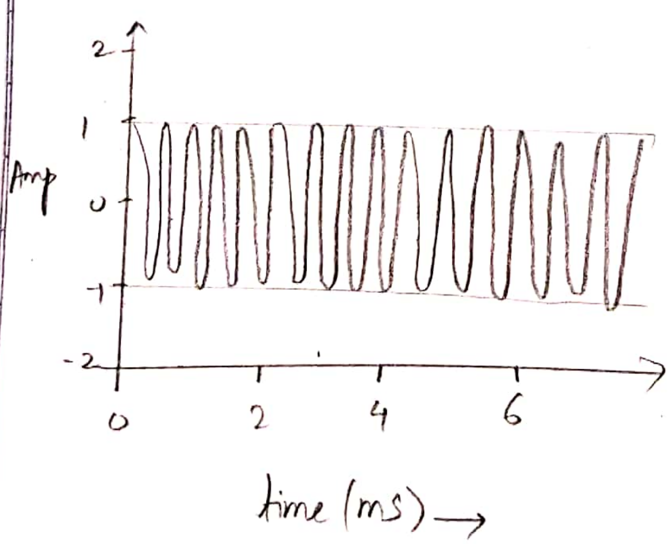


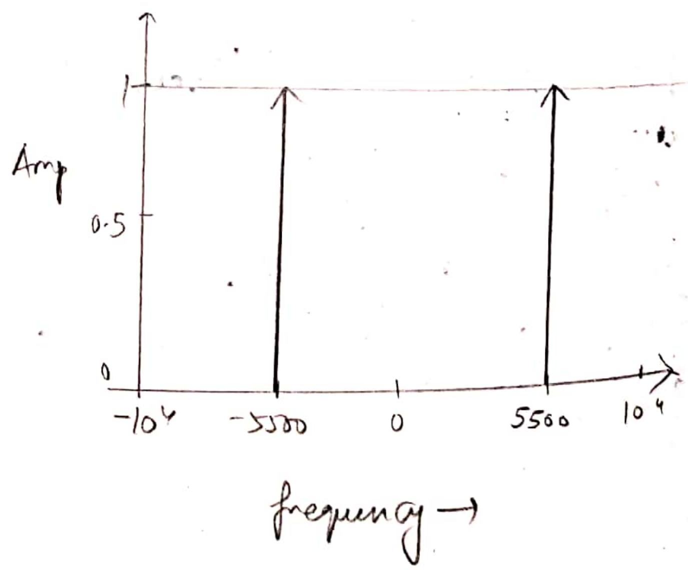
Carrier Signal





Modulated Signal





Advantages:

1) Bandwidth or spectrum space occupied is less than AM & DSB signal.
2) Power is conserved and high power signal can be transmitted
3) Less amount of noise is present
4) Signal fading is less likely to occur.

Disadvantages:

1) The generation and detection of SSB is a complex process
2) Quality of the signal gets affected unless the SSB transmitter and receiver have an excellent frequency stability

Applications:

1) For power saving requirements and low bandwidth requirements.
2) In land, air and maritime mobile communication
3) In point-to-point communications
4) In radio communications
5) In television, telemetry and radar communication
6) In military communications, such as amateur radio.

Conclusion:

Successfully observed and simulated SSB scheme and implemented the waveforms of message/carrier and resultant modulated signal in the time and frequency domain using Matlab Software.