Experiment No. 5

Conventional AM Modulation (Double Side Band-Large Carrier DSB-LC)

Objective: To visualize the message modulating the carrier frequency using Double side band with carrier modulation, which is called conventional AM modulation.

Pre-requests: Basics of MATLAB and fundamentals of signals & systems.

Useful References:

- Lecture Notes of the course,
- Signal processing & Linear Systems, (B. P. Lathi, ©2004, ISBN: 978-0-19-568583-1).
- Communication Systems, (Simon S. Haykin, © 2000, ISBN: 978-0-47-117869-9).

Theory :

The AM system modulates a signal $m(t)$ as

$$m_{DSB-LC}(t) = [1 + a \times m_n(t)] \times A_c \cos(\omega_c t) \qquad \text{Ex 5.1}$$

The Fourier transform of Ex 5.1 is

$$M_{DSB-LC}(\omega) = A_c \Big\{\pi\delta(\omega - \omega_c) + \pi\delta(\omega + \omega_c) + \frac{a}{2}\Big[M_n(\omega - \omega_c) + \frac{a}{2} M_n(\omega + \omega_c)\Big]\Big\} \qquad \text{Ex 5.2}$$

From Ex 5.2, the bandwidth B_T of the transmission is twice wider $m(t)$.

$$B_T = 2W \qquad \text{Ex 5.3}$$

Where W is the bandwidth of the message signal. Further, it can be seen that the carrier signal alone has been appeared in the spectrum equation, Ex 5.2, that is why this amplitude modulation called AM-with Carrier or DSB-LC, or simply AM modulation. In the DSB-LC AM modulation system, the demodulation process can be achieved by using an envelope detector,

$$y(t) = A_c[1 + a\, m_n(t)] = A_c\left[1 + a\, \frac{m(t)}{\max|m(t)|}\right] \qquad \text{Ex 5.3}$$

Then the original message signal can be recovered as,

$$m(t) = \left[\frac{y(t)}{A_c} - 1\right] \frac{\max|m(t)|}{a} \qquad \text{Ex 5.4}$$

The AM demodulation operation does not require the carrier signal at the receiver, therefore, this type of modulation is asynchronous modulation type, but at the expense of the transmission power efficiency of the system.

<u>Procedure</u>: Implementing the DSB-LC modulation.

Use the following MATLAB program to implement the **DSB-LC** AM-modulation, write the program in your PC and run it. The program will ask you to input the carrier amplitudes, and will ask you to input the carrier frequencies.

```
% simulates conventional AM(DSB-LC)
clear all, close all; clc;
Ac=1; % Amplitude of carrier
fc=input('Frequency of carrier [in Hz] Fc = ');% Frequency of carrier
a=input('Modulation index a = '); % Demodulation parameter
wc=2*pi*fc;
Tb=0.1;                           % Bit interval time
T=1/fc/8; Fs=1/T;                 % Sampling period/frequency
Nb=Tb/T; lt=2^(nextpow2(3*Nb)); t=[1:lt]*T; % Time vector
m= ones(Nb,1)*[4 -8 -4]; m=m(:).'; % Message signal m(t)
m=[m, zeros(1,lt-length(m))];  m_max=max(abs(m));
m_cv=Ac*(1+a*m/m_max).*cos(wc*t);  % AM signal
y_dtr=abs(hilbert(m_cv));          % Envelope detector output
y_cv=(y_dtr/Ac-1)*m_max/a;         % Demodulated
plot_MOD(T,lt,m,m_cv,y_dtr,'DSB-LC',y_cv)
```

You will need this function to get the results plotted:

```
function plot_MOD(T,lt,msg,modul,demodul,How,detected,Bd,Ad)
% plots AM signals and their spectra
Fs=1/T; % Sampling Frequency/Period
t=[1:lt]*T; f =[-Fs/2: Fs/lt: Fs/2];  % Time/Freq. vector
M=fftshift(fft(msg));
M=[M M(1)]*T; % Spectrum of Message signal
Modul=fftshift(fft(modul));
Modul=[Modul Modul(1)]*T; % Spectrum of modulated signal
Y=fftshift(fft(demodul));
Y=[Y Y(1)]*T; % Spectrum of demodulated signal
subplot(421), plot(t,msg)
title('Message signal m(t)')
subplot(422), plot(f,abs(M))
title('Spectrum of message')
subplot(423), plot(t,modul)
title([How ' modulated signal'])
subplot(424), plot(f,abs(Modul))
title('Spectrum of modulated signal')
subplot(425), plot(t,demodul)
title('Demodulated signal y(t)')
subplot(426), plot(f,abs(Y))
title('Spectrum Y(f) of y(t)')
if nargin==9
  H=fftshift(fft(Bd,lt)./fft(Ad,lt));
  Hm=abs([H H(1)]); % Frequency Response of LPF
  hold on, plot(f,Hm,'r-')
end
if nargin>6
  Y_dtr=fftshift(fft(detected));
  Y_dtr=[Y_dtr Y_dtr(1)]*T; % Spectrum of detected signal
  subplot(427), plot(t,detected)
  title('Lowpass filtered output y_dtr(t)')
  subplot(428), plot(f,abs(Y_dtr))
  title('Spectrum Y_dtr of y_dtr(t)')
end
```

Perform the following steps,

1. Run the program and record all your results,
2. Change the message signal to $[44\,,0\,,-12$, and record all the results.
3. Change the message signal to $\sin(2\pi Wt)$, where $W = 5\,Hz$, and record all the results.
4. Change the message signal to $\sin(2\pi Wt)$, where $W = 50\,Hz$, and record all the results.
5. Change the message signal to $\text{sawtooth}(2\pi Wt)$, where $W = 5\,Hz$, and record all the results.
6. Change the message signal to $\text{square}(2\pi Wt)$, where $W = 15\,Hz$, and record all the results.
7. Change the message signal to $\sin(2\pi Wt)$, where $W = 2\,Hz$, and let the modulation index $a = 0.25$ record all the results.
8. Repeat step 7 when $a = 1.25$.
9. Repeat step 7 when $a = 1.75$.

Discussion:

1. How to calculate the power of the modulated signal?
2. If there is a phase shift error in the carrier at the receiver side, what will happen to the received signal? Explain it mathematically.
3. From the results you obtained, calculate the bandwidth of the transmitted signals.
4. Calculate the transmission power efficiency for your results in steps 2 to 9.

Good Luck
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