Experiment No. 4

Double Side Band Suppressed Carrier Modulation (DSB-SC)

Objective: To visualize the message modulating the carrier frequency using Double side band suppressed carrier modulation (DSB-SC).

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 DSB-SC system modulates a signal $m(t)$ by multiplying it by a sinusoidal signal called the carrier signal $c(t) = A_c \cos(\omega_c t)$

$$m_{DSB-SC}(t) = m(t) \times A_c \cos(\omega_c t) \qquad \text{Ex 4.1}$$

The Fourier transform of Ex 4.1 is

$$M_{DSB-SC}(\omega) = \frac{A_c}{2}[M(\omega - \omega_c) + M(\omega + \omega_c)] \qquad \text{Ex 4.2}$$

From Ex 4.2, the bandwidth B_T of the transmission is twice wider $m(t)$.

$$B_T = 2W \qquad \text{Ex 4.3}$$

Where W is the bandwidth of the message signal. Further, it can be seen that the carrier signal alone did not appears in the spectrum equation, Ex 4.2, that is why this amplitude modulation called AM-Suppressed Carrier.

In the DSB-SC AM modulation system, the demodulation process can be achieved by multiplying Ex 4.1 by the carrier signal again, with amplitude correction which is $2/A_c$

$$y = m_{DSB-SC}(t) \times \frac{2}{A_c}\cos(\omega_c t) = m(t) + 2m(t)\cos(2\omega_c t) \qquad \text{Ex 4.4}$$

If we see the Fourier transform of Ex 4.4,

$$Y = \frac{1}{2}M(\omega - 2\omega_c) + M(\omega) + \frac{1}{2}M(\omega + 2\omega_c) \qquad \text{Ex 4.5}$$

We can see that the message signal has been translated to its original frequency, which can be recovered by low pass filter.

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

Use the following MATLAB program to implement the **DSB-SC** 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 DSB-AM
clear all, close all; clc;
Ac=input('Carrier Amplitude Ac = '); % Carrier Amplitude
fc=input('Carrier Frequency [in Hz] Fc = '); % Carrier Frequency
wc=2*pi*fc;
Tb=0.1;   % Bit interval time
T=1/fc/8; % Sampling period
Fs=1/T;   % Sampling 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_dsb=Ac*m.*cos(wc*t);          % AM-DSB signal
y_dsb=m_dsb*2/Ac.*cos(wc*t);    % Demodulated signal
N=20; Bd= fir1(N,fc*T); Ad=1;  % 20th-order FIR LPF
y_dtr=filter(Bd,Ad,y_dsb);     % Detected with LPF
plot_MOD(T,lt,m,m_dsb,y_dsb,'DSB-AMSC',y_dtr,Bd,Ad)
```

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.

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.

Good Luck
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