Experiment No. 6

Single Side Band (SSB) AM Modulation

Objective: To visualize the message modulating the carrier frequency using Single side band amplitude 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 :

To conserve the transmission bandwidth, only single side of the AM signal can be used, since both side bands bear the same message signal. In SSB AM modulation, Hilbert transform can be used to generate the modulated signal. Hilbert transform of $m(t)$ can be defined as;

$$\hat{m}(t) = m(t) * \frac{1}{\pi t} \quad \text{Ex 6.1}$$

The Fourier transform of Ex 6.1 is

$$\hat{M}(\omega) = -j\, sign\,(\omega) M(\omega) \quad \text{Ex 6.2}$$

Therefore, the modulated signal in the frequency domain will be

$$M_{SSB}(\omega) = \frac{A_c}{2}[\{M(\omega-\omega_c) + M(\omega+\omega_c)\} \pm \{sign(\omega-\omega_c)M(\omega-\omega_c) - sign(\omega+\omega_c)M(\omega+\omega_c)\}] \quad \text{Ex 6.3}$$

Since only one side will be transmitted, either Upper side band or Lower side band, the bandwidth is halved,

$$B_T = W \qquad \text{Ex 6.4}$$

Where W is the bandwidth of the message signal. In the SSB AM modulation system, the demodulation process can be achieved just like in the DSB-SC modulation system,

$$y_{SSB}(t) = m_{SSB}(t) \times \frac{2}{A_c}\cos(\omega_c t) = m(t)\{1 + 2\cos(2\omega_c t)\} \pm \hat{m}(t)\sin(2\omega_c t) \qquad \text{Ex 6.5}$$

The last equation shows that the signal has been recovered in the first term, while the other terms are high frequency components, which can be filtered out using low pass filter.

<u>Procedure</u>: Implementing the SSB modulation.

Use the following MATLAB program to implement the **SSB** 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 USSB/LSSB-AM
clear all; close all; clc;
U_or_L=input('Upper or Lower Side band? [1 for lower and 0 for upper] = '); %
1 = Lowe side, 0 Upper side
Ac=input('Amplitude of Carrier Ac = ');
fc=input('Frequency of Carrier [in Hz] Fc = ');
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))];  ma=hilbert(m);
tmpc=real(ma).*cos(wc*t); tmps=imag(ma).*sin(wc*t);
if U_or_L<=0;  m_ssb=Ac*(tmpc-tmps); str='Upper side SSB-AM'; % USSB-AM
signal
 else     m_ssb=Ac*(tmpc+tmps); str='Lower side SSB-AM';  % LSSB-AM signal
end
y_ssb=m_ssb*2/Ac.*cos(wc*t); % Demodulated signal
% Digital FIR LPF design
Bd= fir1(20,fc*T); Ad=1;
% Output of LPF as a detector
y_dtr=filter(Bd,Ad,y_ssb);
plot_MOD(T,lt,m,m_ssb,y_ssb,str,y_dtr)
```

```
%This is an optional part, to visualize your results clearly compared with
the original message;
m_ssb=modulate(m,fc,Fs,'amssb');
subplot(423), hold on, plot(t,m_ssb,'r')
y_ssb=demod(m_ssb,fc,Fs,'amssb');
subplot(427), hold on, plot(t,y_ssb,'r')
```

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 $\mathrm{sawtooth}(2\pi Wt)$, where $W = 5\ Hz$, and record all the results.
6. Change the message signal to $\mathrm{square}(2\pi Wt)$, where $W = 15\ Hz$, and record all the results.

<u>Discussion:</u>

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 3 to 6.

Good Luck
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