ELEG 4143: Project 02: Amplitude-Shift Keying (ASK) Signal Frequency Distribution

Due: September 22, 2022

Amplitude modulation can be implemented either with a carrier (AM modulation) or with a suppressed carrier, Double-Sideband, Suppressed-Carrier (DSB-SC). In DSB-SC the transmitted signal can be described by the following equation

$$\phi(t) = m(t)\cos 2\pi f_c t \;\Leftrightarrow\; \Phi(f) = \tfrac{1}{2}\left[M(f+f_c)+M(f-f_c)\right] \tag{1}$$

Demodulation of the DSB-SC signal requires knowledge of both the frequency and phase of the carrier signal. In order to facilitate demodulation, the carrier signal is included in the transmitted signal as shown in the following equation with a dc offset of A

$$\phi_{AM} = \left[A + m(t)\right]\cos 2\pi f_c t \tag{2}$$

For convenience equation 2 can be re-written as

$$\phi_{AM} = A_m\left[1 + \mu\ m(t)\right]\cos 2\pi f_c t \tag{3}$$

where the message, m(t), is normalized to maximum magnitude of 1, ($|m(t)| \leq 1$), the modulation index, μ, is in the range ($0 < \mu \leq 1$), and A_m is the magnitude of the transmitted message. The Fourier transform of equation 2 is

$$\Phi_{AM}(f) = \tfrac{A_m}{2}\left[\delta(f+f_c) + \delta(f-f_c)\right] + \tfrac{A_m\mu}{2}\left[M(f+f_c) + M(f-f_c)\right] \tag{4}$$

where the first term is the transmitted carrier and the second is the sideband message. Equations 3 and 4 are slightly different from equations 4.8b and 4.8c in the textbook [1] to emphasis that modulation index, μ, must be constrained to the range ($0 < \mu \leq 1$) to allow envelop demodulation to be achieved without distortion.

The AM power efficiency is the following equation

$$\eta = \frac{P_m}{1 + P_m}\times 100\,\% \tag{5}$$

where P_m is the average power of the message scaled by μ

$$P_m = \frac{1}{T}\int_0^T |\mu\ m(t)|^2\,dt \;\approx\; \frac{1}{N}\sum_{n=1}^{N}|\mu\ x(n)|^2 \tag{6}$$

and the sideband power, $P_s = P_m/2$.

Project Requirements:

1. Find the transmitted sideband power, P_s, for a sinusoidal message with DSB-SC modulation.
2. Find the transmitted sideband power for a triangular message with DSB-SC modulation.

3. Find the transmitted sideband power and the power efficiency for a sinusoidal message with μ = 0.5 in AM modulation.
4. Publish the results as a single pdf document and upload to Blackboard. One submission per group.

```
%% ELEG 44143 - Project 02 - 2022
% Generate a message signal with amplitude modulation
%
clear; close all; clc;
% Signal default parameters
fs = 2000;                    % Sampling frequency
fc = 500;                     % Carrier frequency
Nper = 2;                     % Number of periods in message
fm = 50;                      % Message frequency
Tp = 1/fm;                    % Period of message signal
T = Nper*Tp;                  % Signal duration
t = (0 : 1/fs : T-1/fs);      % Sampling times
A = 0.0;                      % Message DC Shift ( 0 for DSB-SC or 1 for AM)
Am = 1.0;                     % Message amplitude
mu = 1.0;                     % Modulation index [0 to 1]
w = 0.5;
% Generate the message signal
wavetype = menu('Message Wave Form','Sinusoidal','Triangular');
if wavetype == 1
  message = cospi(2*fm*t);        % Sinusoidal Message Signal
elseif wavetype == 2
  message = sawtooth(2*pi*fm*t,w); % Triangular Message Signal
end
modtype = menu('Modulation Protocol','DSB-SC','AM');
if modtype == 1
  A = 0.0;
  mu = 1;
elseif modtype == 2
  A = 1.0;
  mu = 1.0;
  titleBar = 'Enter a value for mu';
  userPrompt = 'mu =';
  Mu = inputdlg(userPrompt,titleBar,1,{num2str(mu)});
  mu = str2double(cell2mat(Mu));
end
x = Am*(A + mu * message);       % Transmitted Message Signal
% Amplitude Modulation
y = ammod(x, fc, fs);            % Amplitude Modulation
figure()
plot(t,x,'Linewidth',2);grid
xlabel('t (sec)');ylabel('x(t)')
title('Transmitted Message Signal')
```

```
figure()
plot(t,y,t,x,'Linewidth',2);grid
xlabel('t (sec)');ylabel('y(t)')
title('Amplitude Modulated Signal with Transmitted Message Signal')
legend('DSB-SC','Message')
% Spectrum of X (message) and Y (amplitude modulated signal)
X = fft(x);
lenX = length(X);
X = abs((X/lenX).^2);                    % Power Spectral Density (PSD)
X = fftshift(X);
Y = fft(y);
Y = abs((Y/length(Y)).^2);               % PSD
Y = fftshift(Y);
f = (-lenX/2:lenX/2-1)*fs/lenX;
figure()
stem(f,X,'fill');grid;
xlabel('f (Hz)'); ylabel('|X(f)|^2')
title('Message Signal Power Spectral Density')
figure()
stem(f,Y,'fill');grid;
xlabel('f (Hz)'); ylabel('|X(f)|^2')
if modtype == 2
  title(['Amplitude Modulated Signal PSD, \mu = ',num2str(mu)])
else
  title('Amplitude Modulated Signal Power Spectral Density')
end
%% Power Calculations
% Power of the message, modulated signals (Ps), power efficiency for AM
% Enter your code here to calculate the power and efficiency values.
```

References:

1. B P Lathi, Zhi Ding. Modern Digital and Analog Communications (5th ed). Oxford University Press, 2018.