Experiment No. 8

Angle Modulation/Phase Modulation

Objective: To visualize the message modulating the carrier frequency using Phase 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 :

Angle modulation is a non linear modulation operation. Angle modulation has two types of modulations; Frequency modulation (FM) and Phase modulation (PM). PM modulation can be expressed as follows:

$$m_{PM}(t) = A_c \cos\left(\omega_c t + k_p m(t)\right) \qquad \text{Ex 8.1}$$

Where k_p is the phase modulation deviation constant. Suppose that the message signal is a sinusoidal type as follows:

$$m(t) = a \cos\left(\omega_m t\right) \qquad \text{Ex 8.2}$$

Substituting Ex 8.2 in Ex 8.1 yields

$$m_{PM}(t) = A_c \cos\left(\omega_c t + \beta_p \cos(\omega_m t)\right) \qquad \text{Ex 8.3}$$

Where $\beta_p = k_p a$. If the message signal is not sinusoidal one, then the modulation index, β_p will take the form

$$\beta_p = k_p \max|m(t)| \qquad \text{Ex 8.4}$$

On the other hand, the bandwidth of the PM modulated signal can be calculated approximately using Carson's rule

$$B_T = 2(\beta_p + 1)W \qquad \text{Ex 8.5}$$

Where W is the bandwidth of the message. The amplitude of the modulated signal is constant, therefore, the power of the transmitted signal can be determined as

$$P_{PM} = \frac{A_c^2}{2} \qquad \text{Ex 8.6}$$

The transmitted signal $m(t)$ can be retrieved from the PM modulated signal by accomplishing a differentiation operation on the phase of the low pass equivalent signal and divide the results by the deviation constant, k_p,

$$\theta(t) = k_p m(t) \xleftrightarrow{divide\ by\ k_p} m(t) \qquad \text{Ex 8.6}$$

Procedure: Implementing the DSB-LC modulation.

Use the following MATLAB program to implement the **PM**-modulation, write the program in your PC and run it.

```
% simulates PM Modultion
clear all; close all;clc;
Ac=1; fc=50;  wc=2*pi*fc; % Amplitude/Frequency of carrier
Tb=0.1; ts=1/fc/8; fs=1/ts; %bit interval, sampling period/freq
Nb=Tb/ts; lt=2^(nextpow2(3*Tb/ts)); t=[1:lt]*ts; % time vector
m=4*[ones(1,Nb), -2*ones(1,Nb), -ones(1,Nb)]; % Message signal
m=[m, zeros(1,lt-length(m))];
kP=0.01;%deviation constant 30*ts
kP=30;
m_PM=Ac*cos(wc*t+kP*m); %PM signal
%demodulation
th=unwrap(angle(hilbert(m_PM)))-wc*t; %phase of analytic signal
y_PM=th/kP; % demodulated signal
plot_MODmy(ts,lt,m,m_PM,y_PM,'PM')
```

You will need this function to get the results plotted:

```
function plot_MODmy(T,lt,msg,modul,demodul,How)
% plots PM 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(321), plot(t,msg)
title('Message signal m(t)')
subplot(322), plot(f,abs(M))
title('Spectrum of message')
subplot(323), plot(t,modul)
title([How ' modulated signal'])
subplot(324), plot(f,abs(Modul))
title('Spectrum of modulated signal')
subplot(325), plot(t,demodul)
title('Demodulated signal y(t)')
subplot(326), plot(f,abs(Y))
title('Spectrum Y(f) of y(t)')
```

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 $-square(2\pi Wt)$ where W = 3 Hz, and record all the results.
4. Change the deviation constant k_p to 5 and repeat steps 1 to 3.
5. Change the deviation constant k_p to 15 and repeat steps 1 to 3.
6. Change the deviation constant k_p to 30 and repeat steps 1 to 3.

Discussion:

1. How to calculate the power of the modulated signal?
2. From your results, estimate the bandwidth of the modulated signals.
3. How to generate PM signals? Use your class lectures.

Good Luck
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