Lab Com1

Analog and Digital Modulation

1. Analog Modulation

1.1 Background

Consider a carrier $c(t) = \cos(2\pi f_c t)$ and the message signal $m(t)$ that may take various waveforms, the modulated signal can be represented as $u(t)$. In analog communication, there are three modulation techniques: amplitude modulation (AM), phase modulation (PM), and frequency modulation (FM). In this experiment, we are going to apply four modulation schemes (AM, DSB-AM, FM and PM) on four types of signal (namely m_1, m_2, m_3 and m_4) to observe the output.

The general equation for these modulation schemes are given as:

$$u(t) = A_c[1 + k_a m(t)]\cos(2\pi f_c t) \quad \text{(AM)}$$

$$u(t) = A_c k_a m(t)\cos(2\pi f_c t) \quad \text{(DSB-AM)}$$

$$u(t) = A_c m(t)\cos\big(2\pi f_c t + \phi(t)\big); \phi(t) = k_p m(t) \quad \text{(PM)}$$

$$u(t) = A_c m(t)\cos\big(2\pi f_c t + \phi(t)\big); \phi(t) = 2\pi k_f \int_{-\infty}^{t} m(\tau)d\tau \quad \text{(FM)}$$

1.2 Instructions

In this part, we will generate AM, DSB-SC AM, PM, and FM waveforms using MATLAB. Then, we will observe and analyze the modulated waveforms in both time and frequency domains.

i. Open a MATLAB script and type the MATLAB code given in the next page.

ii. Examine and then run the file; observe that by selecting the message signal **mt** and the modulated signal **ut**, you are able to see different modulation types: AM, DSB-SC AM, PM, and FM, for the four types of signal. (A total of 16 sets of message-modulated pairs)

   (Q1) What are the four types of waveform being used?

iii. Generate these waveforms one by one and record the MATLAB plots.

   (Q2) Confirm that they are the theoretically expected waveforms, by writing in your lab report the mathematical expression for each one.

   (Q3) Explain the code used for every modulation scheme.

iv. Repeat the experiment by varying the values of the modulation constants (k_p, k_f and k_a). [hint: use values that you think are suitable]

   (Q4) What do you observe?

v. Given the following message signal, write code to perform the modulations and record the output. $u(t) = \begin{cases} t; 0 \le t < 1 \\ -t + 2; 1 \le t \le 2 \\ 0; otherwise \end{cases}$

vi. Include in your lab report, the general comments and a description of what you have learned from this experiment.

MATLAB CODE:

```
Prepared by Assoc. Prof. Ir. Dr. Chow Chee Onn
clear all; close all

% Parameter Settings
fs = 2e3; t0 = 0; tN = 4; t = t0:tN/fs:tN-1/fs;
Am = 1.0; Ac = 1.0;
fc = 10; fm = 1;
kp = 45; kf= 100; ka = 1.5;    % modulation index
a = 0.25;
T = t(end); t1 = numel(t)/2;   % Adjust time scale of 4 seconds

% Carrier
ct = Ac*cos(2*pi*fc*t);

% Message signals
m1 = a*cos(2*pi*fm*t);
m2 = [Am*ones(1,t1) -Am*ones(1,t1)];
m3 = [Am*t(1:t1) -6*Am*(t(t1+1:end)-T)/(T-t(t1))];
m4 = [Am*t(1:t1).^2/2 2+Am*(-t(t1+1:end).^2+2*T*t(t1+1:end)+t(t1)^2-2*T*t(t1))/(T-t(t1))];

% AM
AM_m1 = Ac*(1 + ka*m1).*cos(2*pi*fc*t);
AM_m2 = Ac*(1 + ka*m2).*cos(2*pi*fc*t);
AM_m3 = Ac*(1 + ka*m3).*cos(2*pi*fc*t);
AM_m4 = Ac*(1 + ka*m4).*cos(2*pi*fc*t);

% DSB-AM
DSB_m1 = Ac*ka*m1.*cos(2*pi*fc*t);
DSB_m2 = Ac*ka*m2.*cos(2*pi*fc*t);
DSB_m3 = Ac*ka*m3.*cos(2*pi*fc*t);
DSB_m4 = Ac*ka*m4.*cos(2*pi*fc*t);


% PM
PM_m1 = Ac*cos(2*pi*fc*t + kp*m1);
PM_m2 = Ac*cos(2*pi*fc*t + kp*m2);
PM_m3 = Ac*cos(2*pi*fc*t + kp*m3);
PM_m4 = Ac*cos(2*pi*fc*t + kp*m4);

% FM
FM_m1 = Ac*cos(2*pi*fc*t + kf/fm*a*sin(2*pi*fm*t));
FM_m2 = Ac*cos(2*pi*fc*t + kf*m3);
FM_m3 = Ac*cos(2*pi*fc*t + kf*m4);
FM_m4 = Ac*cos(2*pi*(fc + kf*m4).*t);
```

```
% Select a message signal and modulated signal to download and plot
mt = m1;
ut = FM_m1;
mt = mt / max(abs(mt)); ut = ut / max(abs(ut));       % Normalization

% Plot the waveforms
subplot(2,1,1); plot(t,mt,'LineWidth',4,'Color','Red')
ylabel('Amplitude','FontSize',12,'FontWeight','bold'); title('Message signal','FontSize',12,'FontWeight','bold')
axis ([-(max(t)-min(t))*0.0 max(t)*1.0 min(mt)*1.1 max(mt)*1.1]);set(gca,'FontSize',16);

subplot(2,1,2);plot(t,ut)
ylabel('Amplitude','FontSize',12,'FontWeight','bold')
title('... Modulation of the message signal','FontSize',12,'FontWeight','bold')
set(gcf,'Color',[1 1 1]);set(gca,'FontSize',16);
```

2. Digital Modulation

2.1 Background

Digital modulation typically aims to transport digital data between two or more nodes. In radio communications this is usually achieved by adjusting a physical characteristic of a sinusoidal carrier, either the frequency, phase, amplitude. This is performed in real systems with a modulator at the transmitting end to impose the physical change to the carrier and a demodulator at the receiving end to detect the resultant modulation on reception. In this experiment, we will investigate three types of digital modulation schemes, namely Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK).

2.2 Instructions

i. Open a Matlab script and type the Matlab code given below.
ii. Examine and then run the file.
    (Q1) Explain the code used for ASK, FSK and PSK by giving the equation.
    (Q2) For each modulation methods, identify the key parameters that affect the modulation and repeat the experiments by varying the value of these parameters.
iii. Record the modulation results.
    (Q3) Analyse the results.
iv. Confirm that the demodulation results are correct.
    (Q4) Explain the code used for demodulation.
v. Include in your lab report, the general comments and a description of what you have learned from this experiment.

MATLAB CODE:

Prepared by Assoc. Prof. Ir. Dr. Chow Chee Onn

```
clc; clear all; close all

%Binary Information & Bit Period
x=[1 0 1 1 0 0 1];
bp=0.000001;
bit=[];
for n=1:1:length(x)
   if x(n)==1;
     se=ones(1,100);
   else x(n)==0;
      se=zeros(1,100);
   end
    bit=[bit se];
end

%Some common parameters
A=5;
br=1/bp;
f=br*10;
t2=bp/99:bp/99:bp;
ss=length(t2);

%ASK
A1=A;
A2=0.5*A;
m1=[];
for (i=1:1:length(x))
   if (x(i)==1)
      y=A1*cos(2*pi*f*t2);
   else
      y=A2*cos(2*pi*f*t2);
   end
   m1=[m1 y];
end

%FSK
f1=f;
f2=0.5*f;
m2=[];
for (i=1:1:length(x))
   if (x(i)==1)
      y=A*cos(2*pi*f1*t2);
   else
      y=A*cos(2*pi*f2*t2);
   end
   m2=[m2 y];
end

%PSK
m3=[];
for (i=1:1:length(x))
   if (x(i)==1)
      y=A*cos(2*pi*f*t2);
   else
      y=A*cos(2*pi*f*t2+pi);
   end
   m3=[m3 y];
end

%plot
t1=bp/100:bp/100:100*length(x)*(bp/100);
figure;
subplot(4,1,1);
plot(t1,bit,'lineWidth',2.5);grid on;
axis([ 0 bp*length(x) -.5 1.5]);
ylabel('amplitude(volt)');
xlabel('time(sec)');
title('transmitting information as digital signal');

t3=bp/99:bp/99:bp*length(x);
subplot(4,1,2);
plot(t3,m1);
xlabel('time(sec)');
ylabel('amplitude(volt)');
title('waveform for binary ASK modulation');

subplot(4,1,3);
plot(t3,m2);
xlabel('time(sec)');
ylabel('amplitude(volt)');
title('waveform for binary FSK modulation');

subplot(4,1,4);
plot(t3,m3);
xlabel('time(sec)');
ylabel('amplitude(volt)');
title('waveform for binary PSK modulation');
```

```
%Demodulation
%ASK
mn1=[];
for n=ss:ss:length(m1)
 t=bp/99:bp/99:bp;
 y=cos(2*pi*f*t);
 mm=y.*m1((n-(ss-1)):n);
 t4=bp/99:bp/99:bp;
 z=trapz(t4,mm);
 zz=round((2*z/bp));
 if(zz>(A1+A2)/2)
  a=1;
 else
  a=0;
 end
 mn1=[mn1 a];
end
disp('(ASK)Binary information at Reciver :');
disp(mn1);

%FSK
mn2=[];
for n=ss:ss:length(m2)
 t=bp/99:bp/99:bp;
 y1=cos(2*pi*f1*t);
 y2=cos(2*pi*f2*t);
 mm=y1.*m2((n-(ss-1)):n);
 mmm=y2.*m2((n-(ss-1)):n);
 t4=bp/99:bp/99:bp;
 z1=trapz(t4,mm);
 z2=trapz(t4,mmm);
 zz1=round(2*z1/bp);
 zz2= round(2*z2/bp);
 if(zz1>A/2)
  a=1;
 else(zz2>A/2)
  a=0;
 end
 mn2=[mn2 a];
end
disp('(FSK)Binary information at Reciver :');
disp(mn2);
```

```
%PSK
mn3=[];
for n=ss:ss:length(m3)
 t=bp/99:bp/99:bp;
 y=cos(2*pi*f*t);
 mm=y.*m3((n-(ss-1)):n);
 t4=bp/99:bp/99:bp;
 z=trapz(t4,mm);
 zz=round((2*z/bp));
 if(zz>0)
  a=1;
 else
  a=0;
 end
 mn3=[mn3 a];
end

disp('(ASK)Binary information at Reciver :');
disp(mn1);
disp('(FSK)Binary information at Reciver :');
disp(mn2);
disp('(PSK)Binary information at Reciver :');
disp(mn3);
```

END