Signals and Systems 2

Giovanni Geraci — Universitat Pompeu Fabra, Barcelona

Lab #5: Modulation/demodulation

High-level objectives:

(a) Use the help system, to learn about Matlab commands and syntax.
(b) Explore and modify examples, to understand third-party code and to write your own.
(c) Get familiar with basic Matlab commands.
(d) Analyze examples of code and relate them with the theory.
(e) Introduce good working habits for creating and presenting reports.

The deliverable for each group consists of a **single .zip file**, including all the materials required at the different exercises, and well as the required manual calculations in paper. The document should be named (please, **be strict** on that, it will be processed automatically):

SiS2_Lab5_NameSurnameMember1_NameSurnameMember2.zip

Submit only **one document per group** to Aula Global.

AM Modulation and Demodulation Lab

Execute the following code:

```
%% AM Modulation and Demodulation Lab

clear,clc,close all;
syms t x1 x2 p1 p2 y1 y2 y dem BPF LPF z w Xr xr

%% Modulating signals

x1 = sinc(t+1);
X1 = fourier(x1);
figure(1); subplot(421); fplot(x1);
xlabel('t (s)'); ylabel('modulating'); axis([-5 5 -1.5 1.5]);
title('Message 1 (time domain)');
figure(2); subplot(421); fplot(abs(X1));
xlabel('\omega (rad/s)'); ylabel('modulating'); axis([-30 30 -0.5 1.5]);
title('Message 1 (frequency domain)');

x2 = -sinc(t-1);
X2 = fourier(x2);
figure(1); subplot(422); fplot(x2);
xlabel('t (s)'); ylabel('modulating'); axis([-5 5 -1.5 1.5]);
```

```
title('Message 2 (time domain)');
figure(2); subplot(422); fplot(abs(X2));
xlabel('\omega (rad/s)'); ylabel('modulating'); axis([-30 30 -0.5 1.5]);
title('Message 2 (frequency domain)');

%% Carrier signals

c1 = 10; % [rad/s]
p1 = sin(c1*t);
P1 = fourier(p1);
figure(1); subplot(423); fplot(p1);
xlabel('t (s)'); ylabel('carrier'); axis([-5 5 -1.5 1.5]);

c2 = 20; % [rad/s]
p2 = sin(c2*t);
P2 = fourier(p2);
figure(1); subplot(424); fplot(p2);
xlabel('t (s)'); ylabel('carrier'); axis([-5 5 -1.5 1.5]);

%% Modulated signals

y1 = x1.*p1;
Y1 = fourier(y1);
figure(1); subplot(425); fplot(y1);
xlabel('t (s)'); ylabel('modulated'); axis([-5 5 -1.5 1.5]);
figure(2); subplot(425); fplot(abs(Y1));
xlabel('\omega (rad/s)'); ylabel('modulated'); axis([-30 30 -0.5 1.5]);

y2 = x2.*p2;
Y2 = fourier(y2);
figure(1); subplot(426); fplot(y2);
xlabel('t (s)'); ylabel('modulated'); axis([-5 5 -1.5 1.5]);
figure(2); subplot(426); fplot(abs(Y2));
xlabel('\omega (rad/s)'); ylabel('modulated'); axis([-30 30 -0.5 1.5]);

%% Combined modulated signal

y = y1 + y2;
Y = fourier(y); Y = simplify(Y);
figure(1); subplot(4,2,[7 8]); fplot(y);
xlabel('t (s)'); ylabel('modulated'); axis([-5 5 -1.5 1.5]);
title('Combined (time domain)');
figure(2); subplot(4,2,[7 8]); fplot(abs(Y));
xlabel('\omega (rad/s)'); ylabel('modulated'); axis([-30 30 -0.5 1.5]);
title('Combined (frequency domain)');
```

```
%% Receiver

% Bandpass filter
w1 = 5; %     **BPF bandwidth lower frequency [rad/s]**
w2 = 15; %     **BPF bandwidth upper frequency [rad/s]**
delta_w = abs(w2-w1);
amp_BPF = 1;
BPF = amp_BPF * ( (heaviside(w-w1) - heaviside(w-w2)) ...
      + (heaviside(w+w2) - heaviside(w+w1)) );
BPF = simplify(BPF);
figure(3); subplot(3,2,[1 2]); fplot(abs(Y));
hold on; fplot(abs(BPF),'--r');
xlabel('\omega (rad/s)'); ylabel('BPF');
axis([ -w2-2*delta_w w2+2*delta_w -2 2 ]); axis([-30 30 -0.5 1.5]);
title('Receiver');

% Demodulator
dem = p1; %     **frequency of demodulating wave**
figure(3); subplot(3,2,3); fplot(dem);
xlabel('t (s)'); ylabel('demodulator'); axis([-5 5 -1.5 1.5]);

% Demodulated message
Y_BPF = Y.*BPF; Y_BPF = simplify(Y_BPF);
y_BPF = ifourier(Y_BPF,w,t); y_BPF = simplify(y_BPF);
z = y_BPF.*dem; z = simplify(z);
figure(3); subplot(3,2,4); fplot(z);
xlabel('t (s)'); ylabel('demodulated'); axis([-5 5 -1.5 1.5]);
Z = fourier(z);

% Lowpass filter
width_LPF = 60; %     **LPF bandwidth [rad]**
amp_LPF = 1; %     **LPF gain**
LPF = amp_LPF * (heaviside(w+width_LPF/2) - heaviside(w-width_LPF/2));
figure(3); subplot(3,2,5); fplot(abs(Z)); hold on; fplot(LPF,'--r');
xlabel('\omega (rad/s)'); ylabel('LPF'); axis([-50 50 -0.5 2.5]);

% Recovered message
Xr = Z.*LPF; Xr = simplify(Xr);
xr = ifourier(Xr); xr = simplify(xr);
figure(3); subplot(3,2,6); fplot(xr);
xlabel('t (s)'); ylabel('recovered'); axis([-5 5 -1.5 1.5]);
```

Assignments:

(a) Analyze and explain the above code.

(b) Change the bandwidth (`width_LPF`) and gain (`amp_LPF`) of the lowpass filter in order to have a correct reconstruction of the first message. Explain. Produce plots.

(c) Now change the bandwidth of the bandpass filter (`w1` and `w2`) and the frequency of the demodulating wave (`dem`) in order to recover the second message, instead of the first one. Explain. Produce plots.