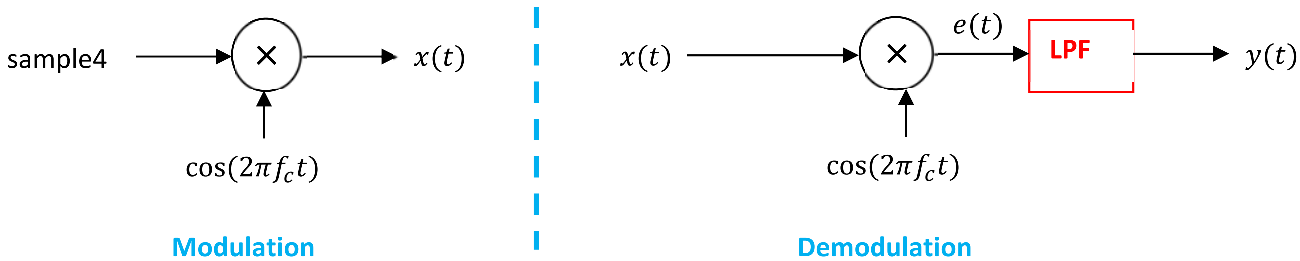
ELEC2100 **Prelab #4**

Objectives

- To be familiar with modulation and demodulation
- To be familiar with sampling

Ex.1 Modulation and Demodulation

The block diagram of modulation and demodulation is shown below.

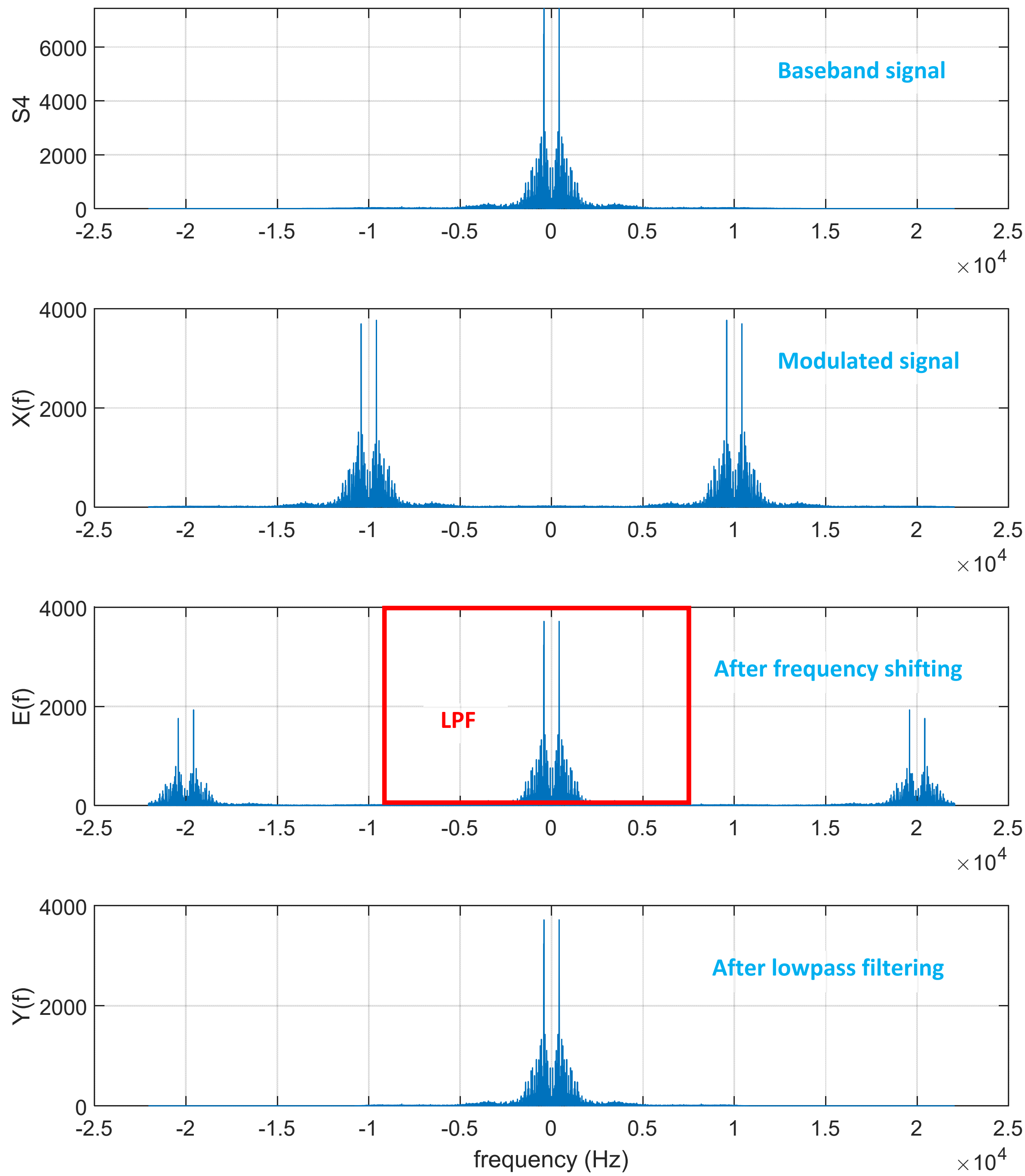



```
[s4,fs]=audioread('sample4.wav');          % read the audio file and sample rate
s4=s4';                                    % transpose
soundsc(s4,fs);                            % hear the audio signal

% Modulation

t=[0:length(s4)-1]/fs;                     % time index
c=cos(2*pi*10e3*t);                        % carrier frequency is 10 kHz (10e3 = 10000)
x=s4.*c;                                   % x is the modulated signal
f=[-length(s4)/2:length(s4)/2-1]*fs/length(s4);   % frequency index (from – fs/2  to  fs/2)

% Demodulation
e=x.*c;                                    % frequency shifting (back to the baseband)
```

Design a lowpass filter (LPF) and plot the magnitude response.
Check the cutoff frequency before performing lowpass filtering.
Plot figure(1).

```
% Use 'butter' to design a lowpass filter        (Write your Matlab codes)
% Use 'filter' to perform lowpass filtering      (Write your Matlab codes)
% You may refer to Ex.2 and Ex.3 in Prelab 3. Set N = 18.


figure(1);
subplot(411); plot(f, abs(fftshift(fft(s4)))); ylabel('S4'); grid;     % spectrum of baseband signal
subplot(412); plot(f, abs(fftshift(fft(x)))); ylabel('X(f)'); grid;    % spectrum of modulated signal
subplot(413); plot(f, abs(fftshift(fft(e)))); ylabel('E(f)'); grid;    % after frequency shifting
subplot(414); plot(f, abs(fftshift(fft(y)))); ylabel('Y(f)'); grid;    % after lowpass filtering
xlabel('frequency (Hz)');
```

figure(1)



Self-check :

- What is the unilateral bandwidth of sample4 ?
- How to decide the cutoff frequency of LPF ?
- Hear the modulated signal (x).
- Hear the demodulated signal (y).
- What is the difference between the modulated signal and demodulated signal ?
- What do you hear if the carrier frequency used in the demodulation is changed to 20 kHz ?
  i.e. The carrier frequencies used in the modulation and the demodulation are different from each other.

Ex.2 Sampling

Convert a CT signal $x(t) = \cos(40000\pi t)$ into DT sequence using two different sampling frequencies.
Plot the sequences in the time domain.
Plot the magnitude spectrums versus the **actual** frequency (in Hz).

```
N=1000;                                                  % number of points
n=0:N-1;                                                 % n index

fs1=25e3;                                                % sampling frequency 1 (25 kHz)
x1=cos(2*pi*20e3*n/fs1);                                 % x is sampled using fs1 = x1[n]
f1=[-N/2:N/2-1]*(fs1/N);                                 % frequency index for x1

figure(2)
subplot(211); stem(n,x1,'.'); ylabel('x1[n]'); xlabel('n');   % plot the DT signal x1
grid; axis([0  20  -1  1]);

subplot(212); plot(f1, abs(fftshift(fft(x1))/length(x1)));    % plot magnitude spectrum of x1
grid; ylabel('|X1|'); xlabel('freuqency (Hz)');


fs2=200e3;                                               % sampling frequency 2 (200 kHz)
x2=cos(2*pi*20e3*n/fs2);                                 % x is sampled using fs2 = x2[n]
f2=[-N/2:N/2-1]*(fs2/N);                                 % frequency index for x2

figure(3)
subplot(211); stem(n,x2,'.'); ylabel('x2[n]'); xlabel('n');   % plot the DT signal x2
grid; axis([0  20  -1  1]);

subplot(212); plot(f2, abs(fftshift(fft(x2))/length(x2)));    % plot magnitude spectrum of x2
grid; ylabel('|X2|'); xlabel('freuqency (Hz)');
```

Self-check :
- What is the signal frequency (in Hz) from the mathematical expression ?
- What is the signal frequency (in Hz) shown in figure(2) and figure(3) ?
- Can you explain the result observed in figure(2) and figure(3) using sampling theorem ?
- Can you write down the mathematical expressions of sampled sequence $x1[n]$ and $x2[n]$?
- What is the normalized frequency of $x1[n]$?
- What is the normalized frequency of $x2[n]$?
- What is the relationship between actual frequency and normalized frequency ?