Modulation and Coding - Report

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Chapter 1

Exercise 1

1.1 Question 1

For the first question, I use this Matlab script to sample all signals:

```
Fe = 8000; % Sampling frequency
Te = 1/Fe; % Sampling period
L = 8; % Number of samples
t = (0:L-1)/Fe; % Chosen times for samples
f = 0:Fe/L:Fe-Fe/L; % Chosen frequency for samples
x = 1+0*t; % Expression of the signal
y_fft = fft(x); % Calculate the DFT
subplot(311);
stem(f,abs(y_fft)); % Plot the spectrum of the signal
xlabel('Frenquency');
ylabel('Amplitude');
subplot(312);
stem(f,real(y_fft)); % Plot the real part of the DFT
xlabel('Frenquency');
ylabel('Amplitude');
subplot(313);
stem(f,imag(y_fft)); % Plot the imaginary part of the DFT
xlabel('Frenquency');
ylabel('Amplitude');
```

For each experiment, \mathbf{x} is changing. \mathbf{L} is set to 8 by default, but can be redefined. In this case, it will be specified.

• x=1, signal length 8 samples

```
x = 1+0*t; % To make the array easily
```



Figure 1.1: Signal's spectrum, DFT's real & imaginary parts

• $x=\sin(2\pi^*1000^*t)$, signal length 8 samples

x = sin(2*pi*1000*t);



Figure 1.2: Signal's spectrum, DFT's real & imaginary parts

• $x=\sin(2\pi^*2000^*t)$, signal length 8 samples

```
x = sin(2*pi*2000*t);
```



Figure 1.3: Signal's spectrum, DFT's real & imaginary parts

• $x=\sin(2\pi^*3000^*t)$, signal length 8 samples

```
4
 Amplitude
    0<u>¢</u>
                             2000
                 1000
                                          3000
                                                      4000
                                                                   5000
                                                                                6000
                                                                                             7000
                                            Frenquency
      × 10<sup>-15</sup>
     1
Amplitude
                               Ŷ
                                                                                  φ
     0
                                                                     Ŷ
                   9
                                            φ
   -1 L
0
                 1000
                                                                   5000
                             2000
                                          3000
                                                       4000
                                                                                6000
                                                                                             7000
                                            Frenquency
     5
Amplitude
     0
    -5
                 1000
                             2000
                                                                   5000
                                                                                6000
                                          3000
                                                      4000
                                                                                             7000
      0
                                            Frenquency
```

x = sin(2*pi*3000*t);

Figure 1.4: Signal's spectrum, DFT's real & imaginary parts

• $x=\sin(2\pi^*4000^*t)$, signal length 8 samples

```
x = sin(2*pi*4000*t);
```



Figure 1.5: Signal's spectrum, DFT's real & imaginary parts

• $x=\sin(2\pi*5000*t)$, signal length 8 samples

```
Amplitude
    0<mark>6</mark>0
                              2000
                 1000
                                           3000
                                                        4000
                                                                     5000
                                                                                  6000
                                                                                              7000
                                             Frenquency
    2 × 10<sup>-15</sup>
Amplitude
                                                                                    φ
                                φ
                                                                       ¢
    0
   -2 L
                 1000
                              2000
                                           3000
                                                       4000
                                                                     5000
                                                                                  6000
                                                                                              7000
                                             Frenquency
    5
Amplitude
    0
   -5 L
0
                 1000
                              2000
                                           3000
                                                       4000
                                                                                  6000
                                                                     5000
                                                                                              7000
                                             Frenquency
```

```
x = sin(2*pi*5000*t);
```

Figure 1.6: Signal's spectrum, DFT's real & imaginary parts

• $x=\cos(2\pi^*2000^*t)$, signal length 8 samples

```
x = cos(2*pi*2000*t);
```



Figure 1.7: Signal's spectrum, DFT's real & imaginary parts

• $x=\cos(2\pi^*4000^*t)$, signal length 8 samples

```
10
Amplitude
    5
    0<mark>6</mark>
0
                  1000
                               2000
                                                                        5000
                                                                                     6000
                                             3000
                                                          4000
                                                                                                   7000
                                               Frenquency
   10
Amplitude
    5
    0<mark>6</mark>
0
                               2000
                                                                                     6000
                  1000
                                             3000
                                                                        5000
                                                          4000
                                                                                                   7000
                                               Frenquency
    1
Amplitude
    0
   -1 L
0
                  1000
                               2000
                                             3000
                                                          4000
                                                                        5000
                                                                                     6000
                                                                                                   7000
                                               Frenquency
```

x = cos(2*pi*4000*t);

Figure 1.8: Signal's spectrum, DFT's real & imaginary parts

• x=-1, signal length 8 samples

x = -1 + 0 * t;



Figure 1.9: Signal's spectrum, DFT's real & imaginary parts



• x=1, signal length 16 samples

Figure 1.10: Signal's spectrum, DFT's real & imaginary parts

 $x=sin(2\pi*1000*t)$, signal length 16 samples •





$x=\sin(2\pi^*1000^*t+0.5\pi)$, signal length 8 samples

x = sin(2*pi*3000*t+0.5*pi);

Figure 1.12: Signal's spectrum, DFT's real & imaginary parts

Figure 1.11: Signal's spectrum, DFT's real & imaginary parts

• $x=\sin(2\pi^*1000^*t)$, signal length 18 samples



Figure 1.13: Signal's spectrum, DFT's real & imaginary parts

• $x=\sin(2\pi^*1000^*t)$, signal length 20 samples

```
L = 20; % Only for this graph x = sin(2*pi*1000*t);
                          10
                      Amplitude
                            5
                                                                                                                  Ģ
                                               ¢
                                                                                                     φ
                                                    φ
                                                                                                ¢
                            0
                                                                        4000
                                                                                   5000
                                                                                              6000
                                      1000
                                                 2000
                                                            3000
                                                                                                         7000
                                                                                                                    8000
                             0
                                                                    Frenquency
                          10
                      Amplitude
                                                                                                                  φ
                            Q
                         -10 L
                                      1000
                                                 2000
                                                            3000
                                                                        4000
                                                                                   5000
                                                                                              6000
                                                                                                         7000
                                                                                                                    8000
                                                                    Frenquency
                             × 10<sup>-15</sup>
                            5
                      Amplitude
                                                                                                             φ
                            0
                           -5
                                      1000
                                                 2000
                                                            3000
                                                                                  5000
                                                                                              6000
                             ί0
                                                                        4000
                                                                                                         7000
                                                                                                                    8000
                                                                    Frenquency
```

Figure 1.14: Signal's spectrum, DFT's real & imaginary parts

• $x=j*sin(2\pi*2000*t)$, signal length 8 samples

x = 1i*sin(2*pi*2000*t);

```
Amplitude
5 5 4
    0<mark>6</mark>
0
                                              3000
                                                           4000
                                                                         5000
                  1000
                                2000
                                                                                       6000
                                                                                                     7000
                                                Frenquency
    5
Amplitude
    0
    -5
                                2000
                  1000
                                              3000
                                                           4000
                                                                         5000
                                                                                                     7000
                                                                                       6000
      Û.
                                                Frenquency
      × 10<sup>-15</sup>
    2
Amplitude
    0
                                                                                         9
                                  Ψ
   -2 L
0
                  1000
                                2000
                                                                         5000
                                                                                       6000
                                              3000
                                                           4000
                                                                                                     7000
                                                Frenquency
```

Figure 1.15: Signal's spectrum, DFT's real & imaginary parts

• $x=j*\cos(2\pi*2000*t)$, signal length 8 samples





Figure 1.16: Signal's spectrum, DFT's real & imaginary parts

• $x=\sin(2\pi^*2000^*t)+j^*\sin(2\pi^*2000^*t)$, signal length 8 samples



x = sin(2*pi*2000*t)+1i*sin(2*pi*2000*t);

Figure 1.17: Signal's spectrum, DFT's real & imaginary parts

• $x=\sin(2\pi^*2000^*t)+j^*\cos(2\pi^*2000^*t)$, signal length 8 samples

Ĥmplitude 0<mark>6</mark> 0 Frenquency × 10⁻¹⁵ Amplitude -2 L Frenquency Amplitude Frenquency

x = sin(2*pi*2000*t)+1i*cos(2*pi*2000*t);

Figure 1.18: Signal's spectrum, DFT's real & imaginary parts

According to these experiments, it is possible to conclude that:

- A constant signal always has a real DFT, positive if the signal is positive, negative in the other case. There is only the first harmonic with an amplitude of: the signal's value multiplied by the number of samples.
- When the signal is out of phase, the spectrum doesn't change, but there is a change in the real and the imaginary part of the DFT (inversion, for a $\frac{1}{2}\pi$ change).
- If the Nyquist-Shannon (Fe < 2f) theorem is not respected, there are a lot of harmonies, and the DFT is not longer unique: it is impossible to recover the original signal. In the case of Fe = 2f, the first harmonic and its image are mingled.
- For a signal with a given frequency f, which respects the Nyquist-Shannon theorem, there is the first harmonic (maximum amplitude) for the frequency f, and there is an image of this harmonic for the frequency f+Fe/2.
- By adding the first harmonic amplitude and its image's one, the number of samples is retrievable. That means that the amplitude of the first harmonic is the half of the number of samples: this looks like the Fourier coefficients.

1.2 Question 2

For this question, I use the same script as for the first one, with these values:

L = 4;