Signals and Systems 2

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Lab #2: Fourier transform

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_Lab2_NameSurnameMember1_NameSurnameMember2.zip

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

1. **Fourier transform of basic signals**

   Analyze and understand the following code:

```
syms x t;
x = heaviside(t+1)-heaviside(t-1);
X = fourier(x);
ax = subplot(311); fplot(x); axis([-3 3 -1 2]); xlabel('t (sec)'); ylabel('x(t)');
ax = subplot(312); fplot(abs(X)); xlabel('\omega (rad/s)'); ylabel('Magnitude
X(j\omega)');
axis([-3*pi 3*pi 0 2]);
ax.XTick = [-3*pi -2*pi -pi 0 pi 2*pi 3*pi];
ax.XTickLabel = {'-3\pi','-2\pi','-\pi','0','\pi','2\pi','3\pi'};
ax = subplot(313); fplot(angle(X)); xlabel('\omega (rad/s)'); ylabel('Phase
X(j\omega)');
axis([-3*pi 3*pi -pi 2*pi]);
ax.YTick = [-pi 0 pi 2*pi];
ax.YTickLabel = {'-\pi','0','\pi','2\pi'};
ax.XTick = [-3*pi -2*pi -pi 0 pi 2*pi 3*pi];
ax.XTickLabel = {'-3\pi','-2\pi','-\pi','0','\pi','2\pi','3\pi'};
```

   Based on what you've learnt:

   (a) **Do the manual calculations**[1] of the Fourier transform (explicit step-by-step integration) of the function $x(t) = u(t+1) - u(t-1)$. Plot your resulting $X(j\omega)$, and compare it with the plots from the example code.

   (b) **Write the code**[2] that **creates and plots**, in an **explanatory way** (as a composition of subplots), the Fourier transform of $x(t) = \frac{1}{\pi}\frac{\sin(t)}{t}$.

[1] Do the **manual calculations in a paper sheet (to be delivered at the end of the session)**, taking a picture for your personal use.

[2] Create a **script**, named as **Lab2-1.m**. Add it to the final .zip file.

2. **System's behavior in time and frequency domains**

Analyze and understand the following code:

```
syms x h t
x = heaviside(t+2)-heaviside(t-2);
h = exp(-t)*heaviside(t);
X = fourier(x);
H = fourier(h);
Y = X.*H;
y = ifourier(Y);
subplot(321); fplot(x); xlabel('t (sec)'); ylabel('x(t)'); axis([-6 6 -1 2]);
title('Time domain');
subplot(323); fplot(h); xlabel('t (sec)'); ylabel('h(t)'); axis([-6 6 -1 2]);
subplot(325); fplot(y); xlabel('t (sec)'); ylabel('y(t)'); axis([-6 6 -1 2]);
ax = subplot(322); fplot(abs(X)); xlabel('\omega (rad/s)'); ylabel('X(j\omega)');
axis([-3*pi 3*pi 0 4]); title('Frequency domain');
ax.XTick = [-2*pi -pi 0 pi 2*pi];
ax.XTickLabel = {'-2\pi','-\pi','0','\pi','2\pi'};
ax = subplot(324); fplot(abs(H)); xlabel('\omega (rad/s)'); ylabel('H(j\omega)');
axis([-3*pi 3*pi 0 1]);
ax.XTick = [-2*pi -pi 0 pi 2*pi];
ax.XTickLabel = {'-2\pi','-\pi','0','\pi','2\pi'};
ax = subplot(326); fplot(abs(Y)); xlabel('\omega (rad/s)'); ylabel('Y(j\omega)');
axis([-3*pi 3*pi 0 4]);
ax.XTick = [-2*pi -pi 0 pi 2*pi];
ax.XTickLabel = {'-2\pi','-\pi','0','\pi','2\pi'};
```

Based on what you've learnt, in relation with the concepts covered in theory and the results of the previous exercise, answer the questions below:[3]

(a) **Make** an explanatory diagram of the system and the involved signals represented by the plots.

(b) **Explain**, qualitatively and mathematically, the relationship between the plots at the right side of the figure.

(c) **Explain**, qualitatively and mathematically, the relationship between the plots at the left side of the figure.

(d) **Explain**, qualitatively and mathematically, how the behavior of the system in the frequency domain is manifested in the time domain.

(e) **Determine**, by manual calculation, the impulse response $h(t)$ of a system that completely cancels out the frequency content of $x(t)$ for $|\omega| > \pi$, preserving the rest of the spectrum without modification.

(f) **Write the code**[4] for **computing and plotting**, in an explanatory way (as a composition of subplots), the processing of $x(t)$ through the system $h(t)$ obtained in (e). **Plot all the relevant signals, except the output in the time domain** $y(t)$.

[3] **Answer in a paper sheet (to be delivered at the end of the session)**, taking a picture for your personal use.

[4] Write the code as a script, named **Lab2-2.m**. Add it to the final .zip file.