University of Brasília

Electrical Engineering Department

Topics in Biomedical Engineering

Exercise 1 - Task 4

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Contents

1 Exercises

1.1 Exercise 1:

1.1.1 a.

The MATLAB's code of Parseval-theorem.m:

```
close all;
% 1D case : Sinusoidal function
Fs=40;f=4;Ts=1/Fs;T=2;t=0:Ts:T-Ts;N=length(t);
x=2*cos(2*pi*f*t);
fx=fft(x);
figure,
subplot(1,2,1), area(t,abs(x.^2)),title('Time Domain');
subplot(1,2,2),area(abs(fx)), title('Frequency Domain');
E1_timedomain=sum(abs(x.^2))
E1_frequdomain=sum(abs(fx.^2))/N
saveas(gcf, sprintf('%s.png', mfilename)); % save image
```

In this code, the Parseval Theorem, in the Equation 1, is being satisfied. The variables E1-timedomain and E1-frequdomain are equal to 160. Evidently, the energy of an periodic signal in the time domain is equal to energy of the transformed signal in the frequency domain divided by the amount of samples. However, the frequency axis wasn't defined and, in this code, this axis isn't the focus of observation.

$$\sum_{n=0}^{N-1} x^2(n) = \frac{1}{N} \sum_{k=0}^{N-1} |X(k)|^2 \tag{1}$$

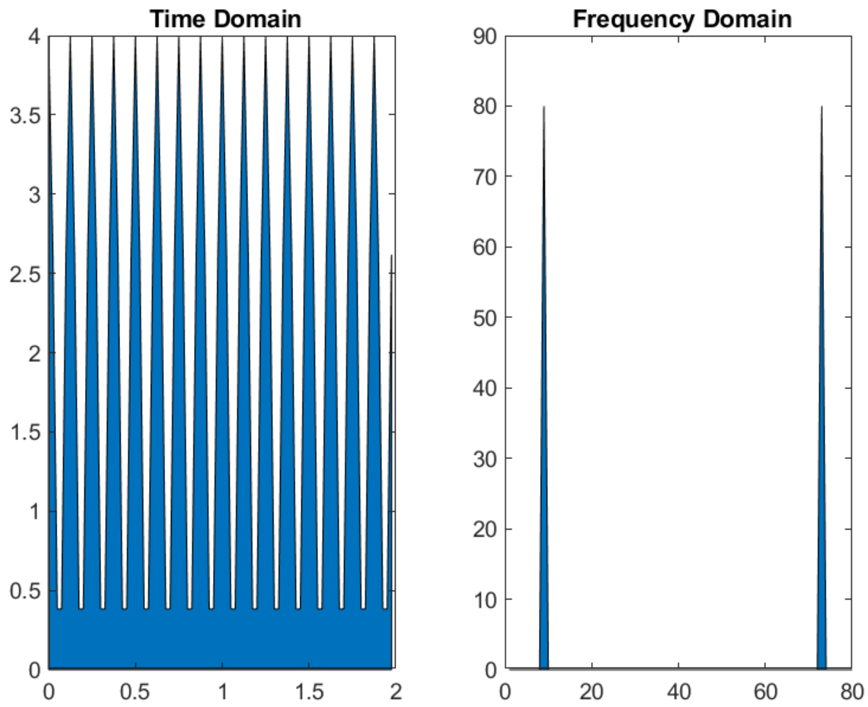

Figure 1: Grapich of the 1a

1.1.2 b.

The MATLAB's code of Parseval-theorem-modificado.m:

```
close all;
% 1D case :  Sinusoidal function
Fs=40; % sampling frequency
f=4; % sinusoid frequency
Ts=1/Fs; % samoling period
T=2; % specific value of time
t=0:Ts:T-Ts; % time axis
N=length(t); % number of points
x=2*cos(2*pi*f*t);

f = (0:N-1)*Fs/N; % frequency axis
fx=(2/N)*fft(x); % fourier transform of x
```

```
fs_mag=abs(fx); % fftmagnitude

figure,
subplot(1,2,1), area(t,abs(x.^2)),title(' Time Domain');
subplot(1,2,2),area(f(1:N/2),fs_mag(1:N/2)), title('Frequency Domain'); % plot only until fs/2

% method 1
E1_timedomain = sum(abs(x.^2))
E1_frequdomain = sum(abs(fx.^2))/N

% method 2
E2_timedomain = sum(abs(x.^2))/N
E2_frequdomain = sum(abs(fx.^2))/N^2
saveas(gcf, sprintf('%s.png', mfilename)); % save image


disp('methods')
out = sprintf('E1_timed: %.4f, E1_freqd: %.4f', E1_timedomain, E1_frequdomain);
disp(out)
out = sprintf('E2_timed: %.4f, E2_freqd: %.4f', E2_timedomain, E2_frequdomain);
disp(out)
```

In this item, the original code was modified and an frequency axis was created with the intention to plot signal energy in the time domain and in the frequency domain with the correct units. In this plot, the frequency axis was restricted only to the positive frequencies ($\frac{fs}{2}$) in order to generate a better visualization and the magnitude of the energy was also normalized.

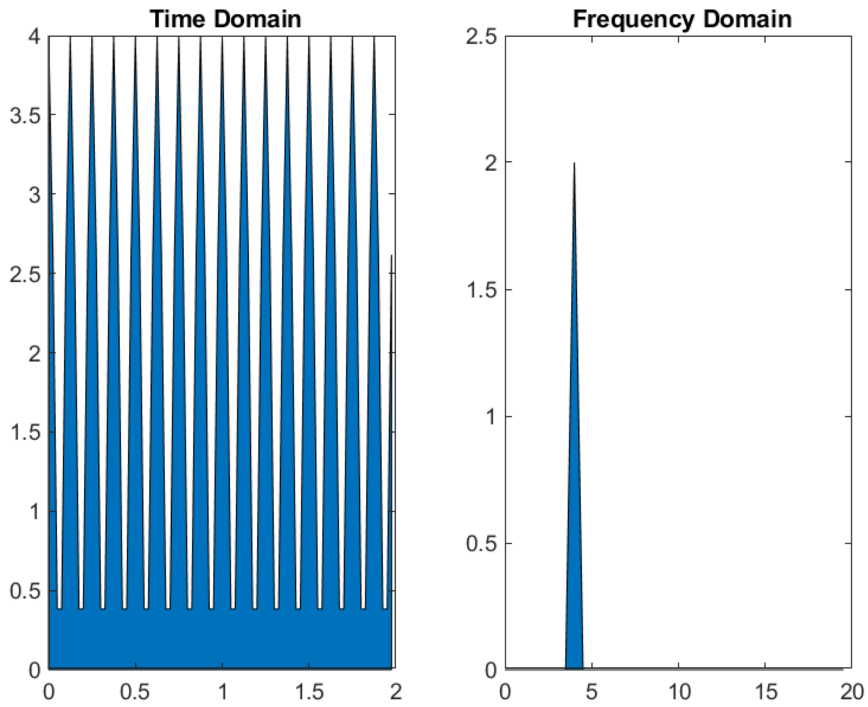

Figure 2: Graphic of the 1b

It's possible to visualize, in the Figure 3, that the Parseval Theorem continues to be satisfied. The equations 2 and 3, which are two versions of the Parseval Theroem, are both respected.

$$\sum_{n=0}^{N-1} x^2(n) = \frac{1}{N} \sum_{k=0}^{N-1} |X(k)|^2 \tag{2}$$

$$\frac{1}{N} \sum_{n=0}^{N-1} x^2(n) = \frac{1}{N^2} \sum_{k=0}^{N-1} |X(k)|^2 \tag{3}$$

```
methods
E1_timed: 160.0000, E1_freqd: 160.0000
E2_timed: 2.0000, E2_freqd: 2.0000
```

Figure 3: Two versions of the Parseval Theorem